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The theme for the third meeting of the Metropolitan Tree Improvement Alliance (METRIA) was "Urban Trees and Their Soils." Members of the program committee were David F. Karnosky (Chairman), Clare Sperapani, and Kim C. Steiner. Clare Sperapani coordinated local arrangements for the meeting which was held at the Cook College campus of Rutgers - The State University of New Jersey. This is the proceedings of that meeting.

ACKNOWLEDGMENTS

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David F. Karnosky
Program Chairman and
Proceedings Editor

Cover Photo Credit: Dr. Thomas S. Elias, The New York Botanical Garden Cary Arboretum

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THE SIZE, DESIGN AND MANAGEMENT OF PLANTING SITES REQUIRED FOR HEALTHY TREE GROWTH [1]

by Thomas O. Perry
School of Forest Resources
North Carolina State University

INTRODUCTION

Too many plantings of trees and shrubs fail within 5 to 10 years after they are established. Cooperative studies sponsored by the United States Forest Service (Southeastern Forest Experiment Station) have attempted to identify the causes of failure and the measures that need to be taken to insure planting programs that yield healthy trees that grow well and function to improve urban environments. The major subject of this paper is the size and design and management of planting sites and containers required for the development of healthy trees of various sizes. However, proper size and design alone are not sufficient to insure success of the tree planting. Current observations indicate the major causes of the failure of tree plantings are:

(1) Improper size, design, after care, and maintenance of the planting and the planting site.

(2) The use of species, races, and varities that are not genetically adapted to the planting site or the region of planting.

(3) Improper lifting, transporting, and storage and handling of the plants during the planting process.

Unless all of these deficiencies are corrected the trees and shrubs of urban plantings will be stunted and short-lived.

TYPICAL TREE ROOTS

An understanding of the problems of growth of tree roots is essential to the proper design of tree planting sites. The following descriptions are presented as a prelude to more detailed specifications for the design of planting sites.

Careful studies reveal that the feeder roots of typical trees are located in the uppermost inches of soil (Krajicek, 1961; Schnur, 1937; Schumacher and Coile, 1960) and grow upward from a system of transport roots that grow horizontally between 4 and 11 inches below the surface. The tree's root system extends outward from the trunk to include a circle that includes diameter several times the height of the tree--far beyond the rain drip. The roots of seven or more trees crisscross to occupy

[1] Metro. Tree Impr. Alliance (METRIA) Proc. 3:1-14, 1980.

the same square foot of soil surface. Even the roots of open-grown trees extend far beyond the tips of their branches.

It is possible to grow a tree with its roots confined to an area which corresponds to the extent of its crown. But trees "free to grow" do not conform to such a pattern. Digging, transplanting and root-confining activities commonly result in the death of the upper portion of the crown and reduction of leaf size and leaf area to 1/4 of its former extent. This is particularly true of trees that have been formerly free to grow. Pruning of tree crowns and provision of extra resources to the residual root system can partially compensate for these effects. In general, it is difficult to constrain a tree's root system to the area outlined by its branch tips without producing a stunted and chlorotic leaf system and dead branches.

Most tree roots conform to this typical pattern of development because the major supplies of oxygen, water and nutrients are confined to the surface layers of the soil. In typical soils of the eastern United States the surface layers are wetted by rains during the growing season while the lower layers of soil are depleted of available moisture by the end of the first weeks of spring.

Roots will penetrate to greater depths in the soil under special circumstances that provide adequate supplies of oxygen and moisture to these lower layers. Some species of trees like longleaf pine have evolved a 2-layered root system to take advantage of sandy soils in surface layer and seasonal fluctuation in the levels of oxygen and water in the lower layers of the soil. Other species like Cypress have developed root systems with special anatomies and biochemistries that permit growth in swampy soils which are characterized by low oxygen supplies. Cypress, spruce, willow and similar species tolerate shallow soils and poor oxygen supplies. However, the roots of these species will penetrate as deeply as those of any desert shrub when the patterns of water and oxygen supply permit.

THE SIZE AND SHAPE OF PLANTING SITES

Healthy trees and shrubs grow rapidly and the planting site must be large enough to accommodate this growth. The data from research on the dimensions and spacings of forest-grown and open-grown trees permit us to improve on the rule of thumb that calls for planting holes with one foot of diameter for each inch of tree caliper plus one foot (Krajicek, 1961; Schnur, 1937; Schumacher and Coile, 1960). This rule of thumb specification merely accommodates the root ball of the transplant and does not allow for growth.

Examination of yield tables developed for many forest tree species growing under full competition reveals the surprising result that the minimum space requirements of different species are very similar and

that within wide limits these space requirements are independent of site quality.

For example, the yield table data for loblolly pine (Schumacher and Coile, 1960) reveal the number of trees vs. diameter relationship that can be described by the equation:

$$\log N = 3.8668 - 1.4774 \log DBH$$

For loblolly pine trees 10 inches in diameter, this corresponds to 245 trees per acre, 178 square feet per tree, or a spacing of 13.3 feet.

The yield table data for upland oaks and hickories (Schnur, 1937) reveal that the relationship between the number of trees per acre and diameter can be described by a very similar equation:

$$\log N = 3.8638 - 1.4987 \log DBH$$

For oak and hickory trees 10 inches in diameter this corresponds to 231 trees per acre, 189 square feet per tree, or a spacing of 13.7 feet between trees.

The 0.4 foot difference in spacing requirements for oaks and pines is less than 3 percent of the average value.

As mentioned earlier, open-grown trees have more leaves and longer and wider crowns than forest-grown trees of comparable diameter. Krajicek, et al (1961) measured the crown widths (CW) and trunk diameters (DBH) of open-grown oaks, hickories, and other hardwoods and described their relationship with the equation:

$$CW = 3.183 + 1.829 (DBH)$$

These equations were used to calculate the space requirements of forest and open-grown trees as listed in Table 1. More time may be required for trees to achieve a given size on different sites, but the minimum space requirements of trees of a given size and habit appears to be relatively unaffected by differences in species or differences in quality of the site.

Review of texts on orchard management give some idea of the space requirements for maximum production of fruit and nut crops. Pears which are slightly fastigiate are commonly planted at spacings between 18 and 25 feet; peaches at spacings between 20 and 25 feet; apples at spacings between 25 and 30 feet. Walnuts and larger pecans are planted at spacings of 60 feet or more (18 trees per acre, Chandler, 1951; Childers, 1954; Gourley and Howlett, 1941).

In general, trees of the family Rosaceae, ornamental cherries, crab-apples, mountain ashes, and the like, should be planted at spacings of

Table 1. Spacing required for trees of various diameters based on yield table data of Schnur 1937, Schumacher and Coile 1966, and Krajieck et al 1961 published with permission of Thomas O. Perry.

	Open Grown Trees			Forest Grown Trees		
DBH	Number of Trees Per Acre	Square Ft. Per Tree	Spacing Between Trees*	Number of Trees Per Acre	Square Ft. Per Tree	Spacing Between Trees**
1	2209	19.7	5.011	7308	6	2.4
5	365	119.3	12.3	655	67	8.1
10	120	362	21.4	231	189	13.7
15	59	736	30.6	126	346	18.5
20	35	1241	39.8	82	531	23.0
25	23	1878	48.9	59	741	27.2
30	16	2647	58.0	45	975	31.2
35	12	3546	67.2	35	1228	35
40	10	4577	76.3	27	1500	38.7

*Assumes a circular crown. To calculate spacing for a square crown:

$$\text{Spacing} = (\text{Square Ft./Tree})^{\frac{1}{2}}$$

**Assumes a square shaped crown. To calculate spacing for a circular crown:

$$\text{Spacing} = \pi/4\ (\text{Square Ft./Tree})$$

20 to 25 feet and oaks and hickories and other large trees should be planted at spacings of 40 to 60 feet if the full effects of their open-grown form is desired. Initial spacings may be closer than this but thinning should be anticipated in the planting design. Olmsted stressed that the best friend of the landscape architect is the ax (Olmsted and Kimball, 1970) and recommended heavy thinnings in the early plantations in Central Park.

Planting designs should allow for growth and thinning. It is disappointing to observe planting beds with trees at the corners which need to be thinned. A tree planted in the center of the bed would have allowed opportunity for thinning without leaving an asymmetric effect.

Trees can develop in holes smaller than specified in the accompanying table. However investigations of these exceptional trees usually reveals a near-by storm sewer or other subterranian device that provides a water supply and aeration and allows escape from otherwise adverse surroundings.

Many of the tree planters along city streets and around shopping malls or tree lawns are deeper than necessary. As described earlier, the roots of most trees are located in the surface foot or so of soil and commonly run horizontally or upward to the surface. Unless special provisions are made to provide oxygen to the deeper layers of soil, there is little reason to have containers deeper than 30 inches. Thirty inches is the height of a typical table and 16 to 18 inches is the height of a typical chair. Containers of this depth are pleasant to the eye and accessible for leaning and sitting.

SOILS IN THE PLANTING SITE

Too often, urban soils represent a complex mix of bricks and broken glass, or dense clay which has been compacted to meet the engineering and load-bearing specifications for buildings or road rights-of-way. The roots of planted trees often grow outward from the planting ball and are unable to penetrate this disturbed bulldozer mixture. Instead they die or procede to grow in a circle around the confines of the planting hole. Percolation is poor and runoff from the surrounding streets can accumulate in the undrained planting hole so the trees suffer alternately from drought and lack of oxygen.

Care should be taken to insure that the space assigned to each tree (not just the planting hole) is provided with soil of proper texture and structure pore space should be adequate for easy penetration of oxygen, water and tree roots. This specification means that the soil must be of a bulk density of about 1.3 with a particle size and organic matter content sufficient to sustain a vigorous mifroflora and fauna.

IRRIGATION AND DRAINAGE

Special programs of watering are an essential part of any intensive horticultural operation. Planting and growing trees in urban situations is no exception. Patterns of water flow through the soil and over the land, are drastically altered during urban development and the contour and drainage of any planting site should accommodate this alteration.

Knowledge of the rates of water lost from forested land and other situations and the sizes of trees and the number of trees per acre permits estimation of the number of gallons of water consumed per day by trees of various sizes. In order to maintain healthy plants the water lost from the system must be replaced whether the loss was through the plant, by evaporation from the soil, or through the soil by drainage.

U. S. Weather Bureau data show that during the summer months an average of 550 - 650 calories of energy strike the earth per square centimeter of surface. This is sufficient to evaporate more than a gram of water which in turn is equivalent to evaporating a layer of water from the surface of the land which is one centimeter or 4/10 of an inch thick. Vertical percolation and down-slope movement account for additional losses so that in very moist soils the water losses per day can approach 2½ centimeters or one inch.

Various workers estimate the rates of water loss through forested ecosystems (Broadfoot, 1958; Brown, 1965; Hewlett, 1961; Metz and Douglas, 1959; Satoo, 1958). The accompanying tables 2, 3, and 4 are based on three possible rates of water consumption; 1/10 of an inch per day, 1/4 of an inch per day, and one inch per day. One tenth of an inch per day is probably representative of rates of water loss in June or July after five or more days without rain. One quarter of an inch per day is representative of rates of water loss observed in typical eastern forest situations of the United States, (Metz and Douglas, 1959). One inch loss per day represents an extreme situation with an ample water supply in a planting site which is excessively drained and has a western exposure or reflector-oven effect from surrounding buildings and pavement.

Irrigation and drainage must be adequate to allow regular flushing of the planting site. City water supplies with high pH's like New Orleans, high alkali contents like Denver, Colorado, high chlorine contents like New York City can produce lethal salt concentrations in the confines of the planting site-a phenomenon similar to that observed with plants that have been kept in the same pot for several years in a residential home. It is recommended that planting sites in confined or paved situations be flushed out 2 or 3 times during the growing season.

SOIL AERATION

Roots must have adequate oxygen supplies and sufficient aeration to

Table 2. Gallons of Water Used Per Day for Varying Rates of Transpiration.

Acre inches of water lost per day	Gallons of water lost per acre/day	Cubic feet of water lost per acre/day
0.1	2.72×10^3	3.63×1
0.2	5.42×10^3	7.25×10^2
0.25	6.78×10^3	9.06×10^2
0.3	8.12×10^3	1.09×10^3
0.4	1.08×10^4	1.45×10^3
0.5	1.36×10^4	1.81×10^3
0.6	1.63×10^4	2.18×10^3
0.7	1.90×10^4	2.54×10^3
0.8	2.17×10^4	2.90×10^3
0.9	2.44×10^4	3.27×10^3
1.0	2.72×10^4	3.63×10^3

Table 3. Water Use of Forest-grown Trees.

Diameter Inches	Gallons of Water Consumed Per Tree Per Day Assuming the Following Acre Inches of Water Consumed Per Day 0.1	0.25	1.0
1	0.1358	0.89	3.58
5	3.78	9.4	37.8
10	10.7	26.6	107
15	19.7	49.2	197
20	29.3	72.8	293
25	40.6	101	406
30	53.5	133	535

Table 4. Gallons of Water Consumed Per Day by Open-grown Trees

DBH Inches	Gallons of Water Consumed Per Tree Per Day Assuming the Following Acre Inches of Water Consumed Per Day 0.1	0.25	1.0
1	1.85	4.63	18.5
5	9.94	24.9	99.4
10	29.7	74.3	297
15	64.7	162	647
20	103.3	258	1033
25	156.5	390	1565
30	214.8	536	2148

prevent the development of toxic concentrations of carbon dioxide, methane, and other gasses. Provision of a good soil and proper drainage will do much to provide this aeration. Care should be taken to avoid sealing the surface with bricks or pavement or black plastic.

Special arrangements of wood, iron, and concrete can be used to allow pedestrians to walk up to the base of a tree without compacting the soil. Cast-iron tree-grates are commonly used for this purpose but at the disadvantage of accumulating cigarette butts, old drink cartons and other trash. Such trash is nearly impossible to remove even with the traditional tongs and nail-pointed sticks of sanitation workers.

Support of the sidewalk on steel girders with a segmented arrangement that allows for easy removal is much more pleasing and easy to maintain than the arrangement of grates. In Denver, the sidewalks surrounding trees are supported 4 to 6 inches above the soil and a bark mulch near the tree trunk prevents trash from slipping into the planting hole. Irrigation is provided beneath the sidewalk. Figure 1 is a representation of such a planting site. Such arrangements are expensive but essential to successful tree plantings in parking lots and sidewalks.

Bricks, cobblestones, and porus concrete devices have been placed directly on the surface of the planting site with the assumption that oxygen and water can penetrate such structures. In most instances the plants in such "semi-paved" situations show severe crown dieback and root growth is confined to the crevices between the bricks and other paving devices. Forestry research has consistently shown the strong negative correlation between tree vigor and the percent stone in the A-horizon.

The combination of a wet fermenting layer of bark mulch and the underlayment of black plastic is consistently lethal to trees. True, weeds will not grow through the plastic--neither will trees!

PROTECTION OF THE PLANTING SITE

The planting site should be protected from de-icing salt, the heat and drying effects of air conditioners and building vents, abnormal lights, steam lines, and other insults.

Sometimes, protection from de-icing salt can be provided by placing the sides of containers above the general grade of pavement. Near highways and bus stops this may be impossible. The salt that comes from the spray of splashing can kill leaves as effectively as the salt that comes from leaching into the planting hole.

Indeed there are many sites where sustained growth of healthy plants is impossible. Records of mortality and replacement can serve to identify such locations of poor risk. Use of plant materials should either

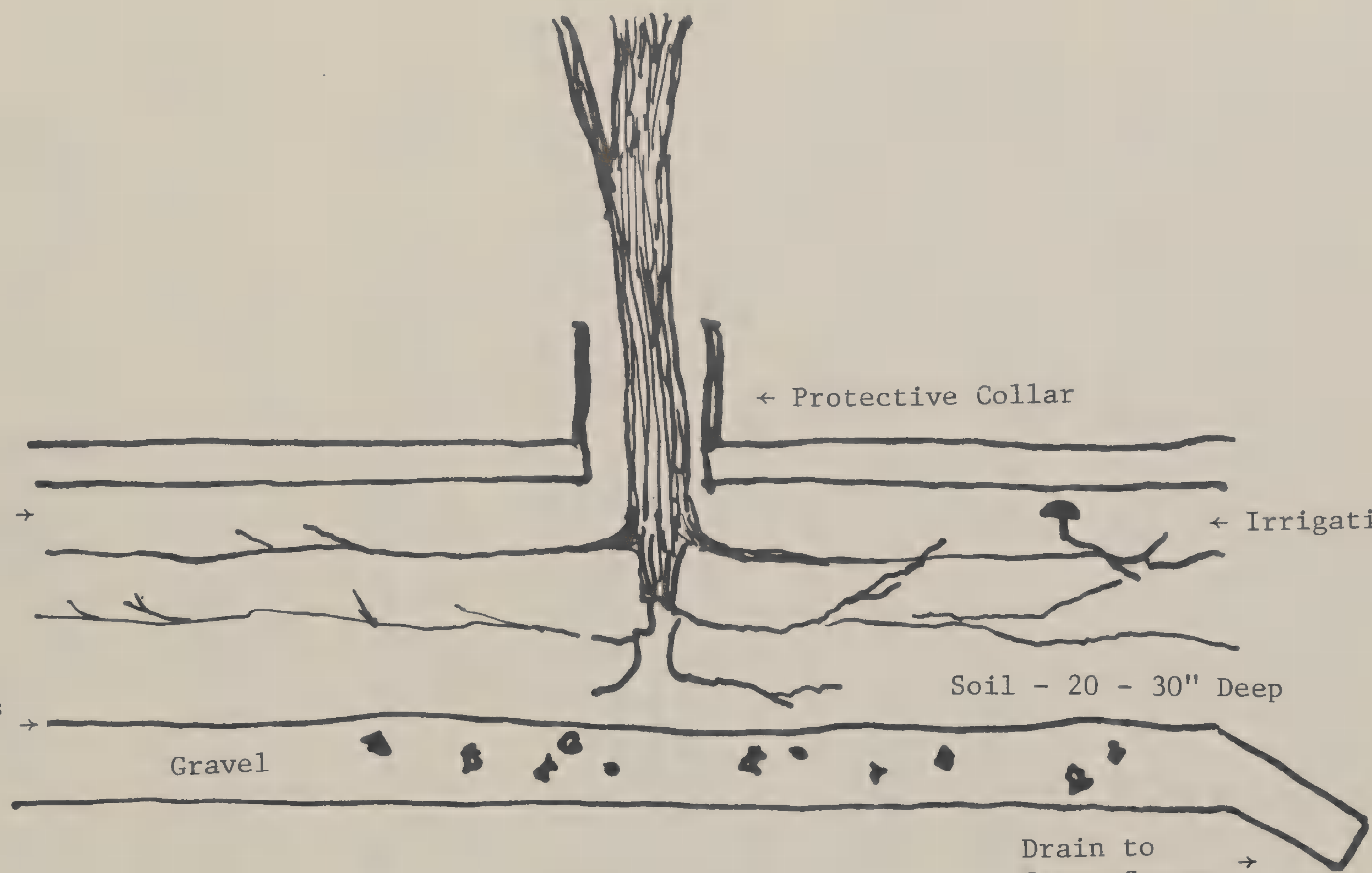

Figure 1. General layout of a proper planting site in paved situations.

be abandoned in such situations or the site design should provide for easy and frequent replacement of the plants.

Scuffling feet and leaning bicycles and thumps by passing cars are a special hazard to the sidewalk planting situation. Protective grills should be higher than the crossbar of a bicycle. Protective collars at the base of the trees should have drain holes in them to prevent trapping of water and should be easily removed for cleaning out of trash.

CONTROL OF COMPETITION

Planting space is precious in urban situations and it is not uncommon to observe groundskeepers and maintenance crews planting prostrate juniper, liriope, ivy, and various flowering annuals in the same space that was assigned for a tree or perennial shrub. Death of the tree is a common result of such over zealous horticulture. A square foot of land can only provide a limited amount of oxygen, water, nutrients and other essentials of life. Hence, the amount of leaves and supporting roots is limited to about 6 square units of leaf surface per square unit of land surface. Tearing up the soil and root system of a tree to plant tulips, petunias, and crysanthimums can only decrease the vigor and size of the tree. There will be a direct competition between the tree's roots and the plant roots for oxygen and water and nutrients. Figure 2 shows an effective arrangement for separating tree roots from the roots of the bedding plants. The bedding plant container should be large enough so that the plants cannot be stolen easily by vandals. Both the raised planter and the tree planter should be provided with adequate water, aeration, and drainage.

PROPER MAINTENANCE

Automatic irrigation systems plug up, salts accumulate, and plants grow too large for their containers. A regular system of inspection and maintenance and replacement should be part of any sidewalk, downtown mall, formal park, or tree lawn planting.

Maintenance requires money. Politicians and businessmen get caught-up in the glories of urban renewal, Arbor Days, and other projects without providing the funds necessary for maintenance. Too many cities have used federal money for elaborate landscape schemes without providing funds for maintenance. Urban plantings should not be undertaken unless such funds are provided. Indeed the federal government should require demonstration of ability to maintain and manage plantings and landscape projects before giving funds to the local governments.

Proper maintenance of trees and other plantings require skilled employees who are literate and who care about the plants they are responsible for. Unfortunately most maintenance workers employed by local governments are marginally literate and unskilled. Two urban

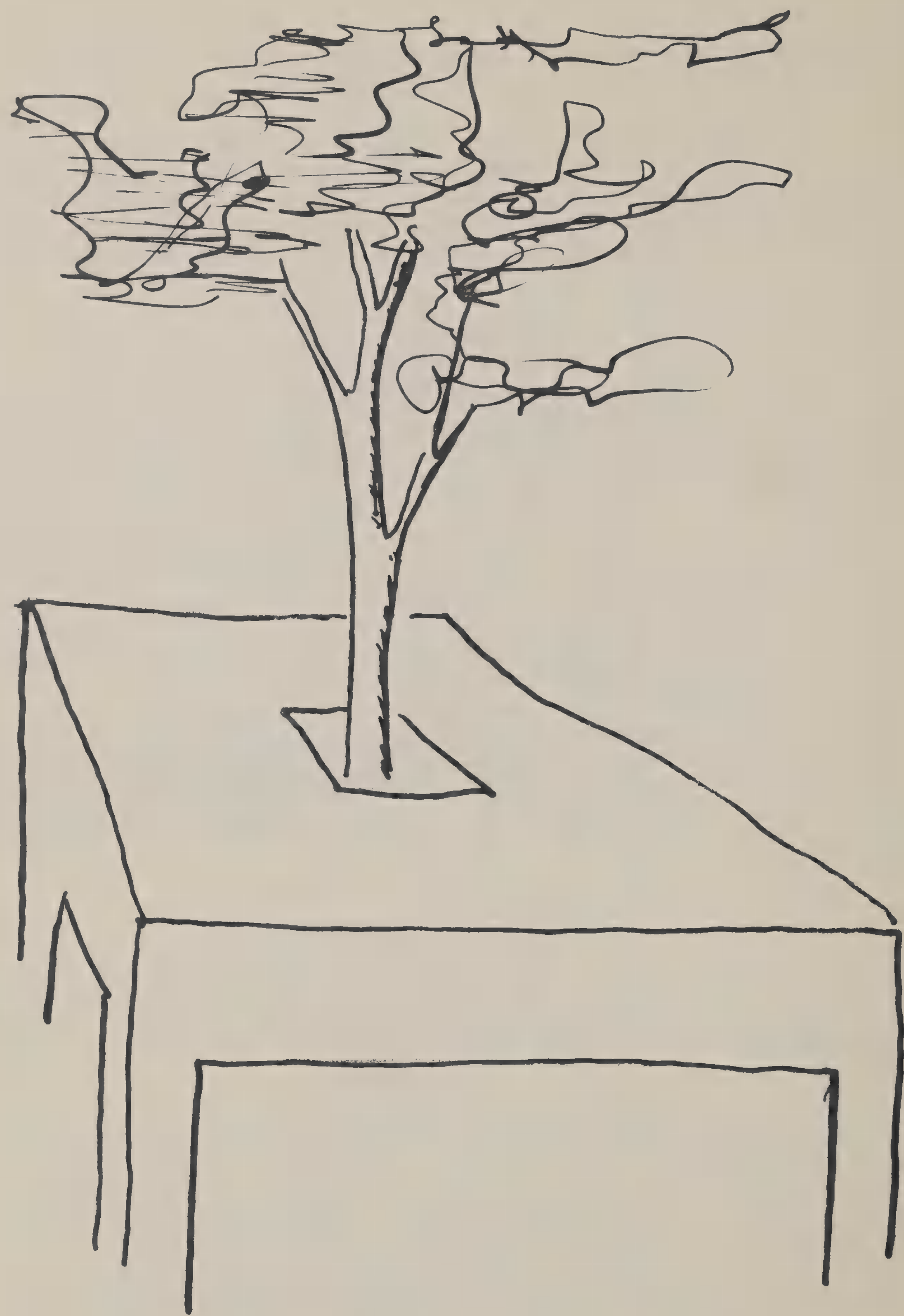

Figure 2. Elevated planter to eliminate competition of roots of bedding plants and trees.

trees out of three show scars of careless use of mowers, weedeaters, and other maintenance equipment. Herbicides are a special hazard in the hands of an untrained worker. Valuable trees were being killed in every city examined in this study because untrained and irresponsible workers were charged with the use of herbicides.

Special training programs plus systems of rewards and penalties for urban employees would do much to improve the health and longevity and beauty of urban plantings.

SUMMARY

Urban planting sites are often very abnormal and require special design and maintenance if the trees placed in them are to grow and be healthy and beautiful. Water needs, design and maintenance practices required for healthy plant growth are described.

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NURSERY PRODUCTION OF TREES IN CONTAINERS[1]

by William Flemer III
Princeton Nurseries
P.O. Box 191
Princeton, NJ 08540

ABSTRACT.--The possibility of growing sizeable shade trees (1½" and over in caliper) in containers is exciting to both arborists and nurserymen. Advantages include reduction in transplant shock, ease of retail storage, extension of the planting and shipping seasons, and less need for nursery space. However, problems include difficulty in overwintering in northern climates, root girdling, potbound trees, and the high cost of growing mix and containers. The suggested best method for cold-weather zones is to re-establish large trees in containers.

THE PRODUCTION OF sizeable shade trees (1½" in caliper and up) in containers has long been a greatly desired goal of arborists and nurserymen alike. It has also been of great interest to the operators of retail garden markets because the storage and handling of bare-root trees at the retail level is a practical impossibility. The arborist is enchanted by the idea of receiving trees thoroughly established in easily removeable containers, trees with every root intact, with a complete balance between root and crown, and not subject to any transplanting shock. Further attractions are the ability to extend the planting season to any time of the year that the ground is not frozen deeply, thus permitting fuller utilization of a smaller, thoroughly experienced planting crew and also permitting additional tree planting whenever budgetary surplusses show up at the close of a fiscal year. Container production also has marked advantages for the grower, the most important one being some relief during brief, hectic digging and delivery seasons, because in effect the trees are "dug" or prepared for shipment when they are planted in the container in which they will be sold. Because container-grown stock can be moved safely throughout the year, the shipping season is enormously extended and the grower can employ a smaller, more stable, and better trained work force. Furthermore it is possible to produce a vastly greater number of trees in containers on an acre of land than on an acre in the open ground, where row spacing must be wide enough to permit cultivation and digging.

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[1]Metro. Tree Impr. Alliance (METRIA) Proc. 3:15-23, 1980.

With all of these obvious advantages, why has container production of large shade trees not entirely supplanted field production, as container growing is in the process of eliminating the field production of junipers, Japanese hollies, azaleas and many other popular ornamental shrubs? The reason is that there are some difficult problems involved in extending container production to large shade trees. One of the most serious problems is deformation of the root system in container-grown plants. Container-grown shrubs which become "pot-bound" are notoriously slow to re-establish themselves in the landscape planting, but once they do so there are no lasting consequences. Particularly in the case of creeping ground-cover plants like the low-growing junipers and cotoneasters, which root along the stems, the effects of root binding are effectively overcome. Other shrubs are low enough so that their tops do not offer the leverage for wind throw. With root-bound shade trees it is another matter however. At first they may seem to become established and grow off vigorously, and everybody is delighted with the good stand and rapid growth. Only as the trees begin to mature and their tops offer serious wind resistance do the delayed problems emerge. In the case of the city of Santa Barbara in California, all the hundreds of Liquidambar trees originally planted out from 5-gallon cans blew down in wind storms as they began to mature. Furthermore, root girdling, which can cause the decline even of a percentage of shade trees transplanted bare root, can be epidemic in the case of pot-bound shade trees.

There are also some disadvantages in container production for the grower too which are not at first apparent. The first of these is the sheer volume of growing mix which is required to produce 2- or 3-inch caliper shade trees in containers large enough for proper root development. It is one thing to transport, prepare and mix the growing medium for 10,000 1-gallon cans and then to fill them and move them to the growing area. It is quite another matter to go through the same processes for 10,000 containers large enough for 2- or 3-inch caliper trees. In the rapidly expanding container-growing segment of the nursery industry, 10,000 1-gallon containers are grown for every 1,000 2-gallon containers and every 250 3-gallon cans, with still larger sizes representing only a tiny fraction of the whole. These relationships reflect not only the expense of handling large volumes of growing mix, but also a time factor which is a real though not so apparent expense.

Nurserymen in general persistently ignore the time factor and the cost of money in computing their production costs. Field growers are vaguely aware that there is an annual cost for acreage owned or rented for production and that a slow-growing crop must command a higher price per plant than a

rapid one. However liner costs, planting costs and subsequent production costs are relatively low in relation to the very big expense of digging the crop at maturity and preparing it for shipment. In container production, the situation is exactly reversed. All of the big expenses - liners, containers, mix, filling, and planting - occur at the front end of the production cycle, for in effect the crop is "dug" when it is planted. In addition to the costs of watering, feeding and trimming, the initial container, mix and planting costs must be carried until the plant is sold. And these costs must be compounded, in today's financial climate, at 1½% per month. In the warm areas of the South where container production is really big, most 1-gallon cans and some 2-gallon crops can be produced in a year's growing period. Three-gallon crops and larger ones take at least two years and cometimes longer. Two- to 3-inch caliper trees, depending upon the species involved, can take 5 to 10 years to produce, starting with a seedling or rooted cutting, so with such high initial costs involved in container production it is easy to see why field production, despite its serious disadvantages, still presents formidable competition in the area of shade trees.

There is one other important consideration in container production in northern climates and this is over-wintering. It is no accident that the explosive increase in container growing is occuring in virtually frost-free parts of the country. The old adage that you can make money in cans only where palm trees will grow outdoors has a lot of truth in it. Unfortunately almost all of the shade trees of species and races suitable for street-tree planting in northern climates (Zone 6 and north) do not thrive in or will not survive the summer heat of southern production areas. If such trees are to be container grown in areas where they will thrive, then there must be special provisions for over-wintering them. While their tops may withstand temperatures of -10°F or colder with impunity, research has shown that root damage for many species begins at 20°F and accelerates rapidly as the root zone temperature drops. One solution for the northern grower is to over-winter his crop in plastic-covered houses. This is costly but still practical for small plants in 1- to 3-gallon cans, but prohibitively expensive for 12- or 14-foot tall trees. The other solution is to move the containers of big trees together and mulch them deeply as some Canadian cities do with potted street trees used in downtown areas. Such a process is labor-intensive in a large operation and the cost of whatever substance is used for mulching is considerable, especially when a 5- to 10-year growing cycle is contemplated, with protection to be provided each winter. Some utility generating plants in the USA are now actively seeking greenhouse growing establishments to locate adjacent to the power

plants and utilize the waste heat produced as a by-product of generating, and this may offer intriguing possibilities for a few northern container growers to winter their crops outdoors over heated ground areas. However, the economic viability of such a system will require considerably more study and research.

PRACTICAL CONTAINER PRODUCTION

From the observations above it can be seen that genuine container production of shade trees from the liner stage to the 2-inch or larger size needed for street tree planting is a doubtful proposition for the northern grower. In areas of England and the Continent with very mild winter climates, successful over-wintering does not present serious problems. For the southern grower in the USA over-wintering presents no difficulties, but the kinds of trees grown must for all practical purposes be limited to species and races which will thrive in the South. This used to be a real drawback because almost all shade tree planting was done in the thriving northern commercial areas where urbanization and population growth were sustained and vigorous. Both the species which a southern nursery could grow and the cost of shipping the big trees to the North made it impractical to grow for a northern market. Now, however, the trends in population have reversed themselves and it is the "sun belt" regions which are thriving and growing the fastest, so the best sales opportunities are more and more in the southern nurseryman's own local areas.

As previously noted, over-wintering is not a problem in container production in the warm South. Even so, it is still not practical to plant a seedling or rooted cutting in the 2- to 3-foot diameter container that will be the size which is ultimately necessary to produce a 2- to 3-inch caliper shade tree. Since the production cycle will take some years to complete, there is no point in watering so large a container area during the early stages of production when the tree is still small. It is much better to get a year or two of growth in a 2-gallon or 3-gallon can and then shift up to the final size. This economy in space is especially significant in the arid Southwest where water is scarce and expensive, often requiring very costly treatment to get the salt level of the water down to non-phytotoxic levels. Furthermore the intensity and quantity of sunlight in the South degrades plastic much more rapidly than in the North and big plastic containers will be hopelessly brittle and even collapse before the end of a long production cycle. Replacing them prior to shipment is costly and very time consuming. The important thing to remember in producing trees in several successive sizes of

containers is to be sure that shift-ups are made on a timely basis and that roots circling the bottom of the smaller container are cut in several places during the transplanting process. If the younger stages once become root-bound, shifting them to larger containers will not forestall the root problem which will show up later on the city streets.

GROWING MIXES

At this point, virtually all container plants in the USA are being grown in some kind of bark or bark mix. The reasons for this development are good ones. Bark is an inexpensive by-product of lumber or paper mills, it can be ground to a uniform granule size, it is reasonably stable and long lasting, and proper composting processes can both sterilize it and eliminate toxic tannins and acids.

While good-looking plants can be grown in pure bark or the bark-peat or bark-rice hulls used on the West Coast, such all-organic media are not satisfactory for shade tree production. The reason can be seen in any group of leftover plants in a retail plant market, particularly in the South. After a season or two the medium level in such leftovers will be found to have been reduced to one-half or even less of its original volume and the plant will have sunk down to a correspondingly lower level in the can. Bacteria and soil fungi use up the organic matter as food and it gradually disappears into the air in the form of carbon dioxide. Exactly the same disappearance of the bark or peat occurs when a large tree in such a substrate is planted on the city street and the tree can subside to far too great a depth for survival.

It is far better for the ultimate development of the tree if it is grown in the mixes of bark and sand or bark and ground shale used by some nurseries in the Southeast rather than in pure bark. In fact, the higher the proportion of shale or gravel in the mix, the better the tree will grow after planting it out. It is true that the heavy mixes increase transportation costs, but when loading 2-inch trees or larger, the bulk of the tops rather than the weight of the balls or containers determines the size of the load. One hundred to 150 trees 2 inches in caliper is the normal load for a standard open trailer; considerably less in a closed trailer.

pH AND FERTILIZING

The pH of composted bark mixes is normally quite low, which is suitable for oak, magnolia, sweet gum, and other acid soil trees. Even they will grow best at about 6.0 and less well at very low levels, so some pH adjustment is often necessary. Trees like honeylocust, Sophora, and ash which grow best at around pH 7.0 normally require the addition of

ground dolomitic limestone to bark mixes to get the pH up to neutral. Different kinds of bark vary in their trace element contents, so it is wise to add fritted trace elements to a section of the container blocks of each variety of tree to see if growth and leaf color are enhanced.

In the arid sections of the country, especially the Southwest where it so rarely rains during the summer, "constant feed" programs in which small amounts of fertilizer are added to the irrigation water on a constant basis work very well. It takes experience and expertise to set and maintain the feeding level, but if it is properly done the resultant growth is phenomenal. In the Southeast and in the northern states, which can experience prolonged rainy spells in the growing period, "constant feed" culture is a much more chancy affair and some hair-raising growth reductions or even plant losses have occurred. Here a safer program is to top dress with granular or pelleted slow-release fertilizer and let the irrigation or rain do the dissolving. Here again expertise, experience, and a constant desire to experiment are necessary for best results. For example, "slow-release" fertilizers dissolve much more rapidly in the prolonged and intense summer heat of the deep South, as more than one southern container grower learned to his horror in the early days.

NORTHERN PRODUCTION

For the many reasons noted above, principally the problems connected with over-wintering large trees in containers, it does not seem likely that 2-inch or larger shade trees will soon be <u>produced</u> (from the seedling stage up) in containers in northern nurseries. However, it may well be practical to <u>re-establish</u> field-grown trees large enough for street planting in containers. Indeed this practice is already being followed in some retail nurseries as a means of extending the selling season. For the retailer it is economically viable because retail prices per individual tree are so much higher than the wholesale prices for volume orders to the trade or to municipalities. Whether re-establishing trees in containers becomes a common method of wholesale production depends largely upon the relationship between the costs of digging the tree bare root and establishing it in a large container and the cost of digging the same tree with a ball of earth and selling it directly. Currently the costs are quite comparable, with the edge going to the B&B route if good piece-work diggers are available. In any size above 3 inches in caliper, container production is impossibly slow and expensive and B&B production will doubtless forever prevail.

Re-establishing trees has one decided advantage over direct B&B digging in that it can often be done in the winter or during the spring in inclement weather when there is little

alternative work available to be done. Thus it can accomplish the container grower's great "edge" over the field grower, preparing stock for shipment at some other time than the shipping season and extending the shipping season as well. There is one important limiting factor, however. A re-potted tree is really not saleable the first spring or even the first fall after it is potted. The following spring, after the first flush of growth, it is comparable in appearance to a freshly dug B&B tree and of course will suffer little or no transplanting shock. Consequently, since 75% or more of all trees sold are shipped in the spring months, re-established trees must be over-wintered through at least one winter, and this means incurring the expense of moving the trees together container-to-container and mulching the root areas or providing some other means of root protection. Such protection need be quite minimal in Zone 7, not prohibitively expensive in Zone 6, but increasingly crucial and exacting in successively colder climatic zones. It is possible that silage or forage choppers and blowers can be adapted to ease the task of mulching, if the production area is large enough and is laid out with this consideration in mind. Nonetheless, even spoiled hay or straw is expensive and so is labor, and northern production areas suffer a distinct handicap.

It is important here to draw a clear distinction between artificially balled trees and those which are re-established in containers. The former are trees dug bare root and later processed by encasing the roots in some form of mix, usually a mixture of peat and straw or peat and sawdust. This mix is held around the roots by a burlap (hessian) bag or wrapping and that is usually covered by an additional bag of polyethylene film to retain moisture. The method is designed to provide living trees with a prolonged "shelf life" for retail garden centers, and the mix is deliberately kept as light as possible for the convenience of the customer who takes his tree home. Almost invariably however, the root system is compressed and distorted by the artificial balling process in an effort to keep the ball as small and as light as possible. Such trees are living when sold and will survive planting out, but they are certainly inferior to dormant bare root or orthodox B&B trees for street planting. The re-potted tree, if it is in a container of adequate size, is a far better product with a more natural and vigorous root system. Furthermore, while only the very easy-to-transplant trees like poplars, weeping willows, and silver maples give good survival in artificial balls, more difficult species like oaks, lindens, and sugar maples are adaptable to container potting.

The mix for the latter process, like good mixes for container production, must combine perfect drainage with good water and fertility retention. The various bark mixes seem to be satisfactory for these requirements. As noted earlier, mixes with a reasonable content of sand, gravel, or ground shale give the best results after planting out, and their increased weight is not a handicap. Indeed, weight is a decided advantage during wind storms, especially in the summer months when trees are in full foliage. The heavier the containers, the less necessary it is to provide bracing or guying for the trees in production in order to avoid resetting large blocks of trees after a summer wind storm.

Fertilizing methods can be "constant feed" via the irrigation water or slow-release fertilizer applied on the surface of the containers, with the advantage to the latter in areas with abundant summer rainfall. The general consensus, as in the case of newly benched florist crops, is that fertilizing should be delayed until the trees have made new top growth after being potted. An interesting concept is irrigation via the small black plastic Chapin Tubes which are frequently used for greenhouse production of chrysanthemums and other pot plants. The advantages are accurate metering of adequate water to each container, particularly important for nearly mature container plants where the foliage canopy is so dense as to interfere seriously with overhead sprinkling. One unexpected drawback has occurred wherever rabbits are about. Their instincts to nip off vegetation to clear pathways has resulted in serious losses of container plants which dry out and die before the cut tube is noticed. Furthermore the cumbersome header tubes with their network of laterals are difficult to move and store. Nonetheless, the Chapin system is very economical of water and is especially valuable for crops which are subject to mildew or other diseases if the foliage is frequently wet.

TRIMMING

It should not be necessary to mention that trees re-established in containers benefit from having their tops shaped and reduced at the time of potting. However, an amusing if ill-informed controversy is raging on the subject in the USA at present. Once in a great while the wisdom of ages of experience can be shown to be false, but this is not such an occasion. It is analagous to recommending adultery. Yes, in rare small-scale experiments it seems to result in no harm. No, as a general rule it leads to very unfortunate results!

CONCLUSION

Shade and flowering trees can successfully be produced in containers in suitable climatic zones. This has been an established practice for small-sized trees for many decades. When the production of larger sizes is contemplated, additional problems occur, especially over-wintering of large trees for a number of winters until they reach saleable size if production is attempted in zones with cold winters. For such areas, re-establishing almost fully grown trees in large containers offers a practical compromise between field production and marketing in containers. In all cases, whether shade trees are entirely grown in containers or re-established in them, it is essential that they are not allowed to become pot-bound, because of the dangers of wind-throw in later years when the trees approach maturity on the city streets.

IDENTIFYING TREES WITH TOLERANCE TO SOIL SALTS[1]

by Alden M. Townsend, Plant Physiologist,
USDA, Science and Education Administration,
Nursery Crops Research Laboratory, Delaware, OH 43015

ABSTRACT.--Urban trees can be injured by deicing salts in the form of salt spray or salts in the soil. Soil salts can be an important factor in causing injury and death of trees planted close to a roadway. Such damage in urban areas usually results from a specific ion effect rather than from an increase in osmotic potential. At Delaware we are looking for systematic techniques and reliable markers to identify trees with tolerance to soil salts.

THE PROBLEM

IN THE UNITED STATES about 12 million tons of deicing salts are applied to Northeastern highways alone each year. Experts predict no decrease in the use of salt in the next decade, despite several alternatives available, such as sand, limestone, and cinders (Dirr 1976; Struzeski 1971). The two principal deicing salts are sodium chloride (NaCl) and calcium chloride ($CaCl_2$). NaCl makes up about 95% of usage, and CaCl about 5% (Dirr 1976).

Although application of salts is necessary for traffic safety, damage occurs to adjacent roadside trees and shrubs. This injury has been well-documented in several American (Dirr 1976; Demeritt 1973; Sucoff 1975; Hanes et al. 1970), Canadian (Hofstra et al. 1979), and European (Buschbom 1968) reports and reviews. Sucoff (1975) has reported specific cases of damage in Germany, New England, and Minnesota. Damage to white pine (Hall et al. 1972) and sugar maple (Baker 1965; Hall et al. 1973; Lacasse and Rich 1964; and Westing 1969) is especially well documented, but many other species have shown injury (Button et al. 1977; Walton 1969).

Highway and street trees estimated to be worth millions of dollars are killed each year as a result of salt (Demeritt 1973). Damage can manifest itself in leaf or needle scorch, branch dieback, disfigurement, loss of vigor, growth reduction, and sometimes death.

Trees can be injured by salt spray (salt deposited on twigs, buds, and needles); by salt that leaches into the soil (soil salt); or by a combination of these two. Many scientists believe that at least along major highways, salt spray causes more damage than salt absorbed from the soil (Dirr 1976; Sucoff 1975). Along city streets or where trees are

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within 9 m of the road, however, soil salt may be equally damaging or more so (Foster and Blaine 1978; French 1959; Hanes et al. 1976). For example, Sucoff (1975) found that damage from soil salt in Minnesota is more serious in the city than on the highway. The probability of soil-salt damage usually is highest within 2.5 m of a salted street, in basins or depressions that collect runoff from salted streets, and next to intersections that demand high salt applications.

Langille (1976) found soil Na increased significantly to distances of 12 m from the edge of an interstate highway in Maine after only one salting season, and soil Cl increased to a distance of 61 m. The Na levels at 6.1 m from the highway edge were 14 ppm before salting and 113 ppm after salting. At the same distances, Cl rose from 22 ppm to 76 ppm. Both Na and Cl increased significantly in hemlock needle tissue at distances of up to 61 m from the highways. Hofstra et al. (1979) reported significant elevation of salt as far as 30 m from a highway in Ontario. Within this distance, they discovered that soil salt contributed to tree injury. Hughes et al. (1975) found that the soluble salt content of soils along Chicago freeways varied considerably, most having 500 to 2000 ppm salt, but a few showing concentrations of 20,000 to 50,000 ppm.

Hutchinson (1970) correlated the Na and Cl of roadside soils in Maine with the number of years they had received deicing salts. He suggested that salts carried over and accumulated within the soils from one year to the next. Various roadside soils across the state at 0, 9.1 m and 18.2 m from the pavement showed average Na values of 281, 139, and 96 ppm respectively; chloride values were 116, 79, 54 ppm.

Salt spray runoff samples from a downtown Chicago Expressway in the winter of 1967 showed a Cl content of 11,000 to 25,000 ppm (Struzeski 1971). Button et al. (1977) showed that infiltration of such salty water could occur in winter, even when the soil was frozen to a depth of 10 cm.

Injury resulting from the presence of soil salts is caused by differences in osmotic potential between the tree and the soil solution; a specific ion effect associated with specific salt ions, such as Na and Cl; or a combination of these two effects (Dirr 1976). High osmotic pressure decreases the availability of soil water and changes the tree's ability to absorb water, causing moisture stress within the plant.

The specific-ion effect involves movement of ions such as Na and Cl into plant cells, where they adversely affect cell membrane stability and metabolism and, at high concentrations, are toxic and may kill the cells. This effect probably is more harmful to city trees than the osmotic effect (Button et al. 1977; Dirr 1976; Spotts et al. 1972).

Salt ions can also diminish the availability of other ions in the soil. Sodium often replaces calcium on the soil colloids and at the same time deflocculates the soil and destroys soil structure. The soil becomes compact, and oxygen levels and microorganism activity are reduced.

Symptoms caused by soil salt have been defined more precisely in deciduous than in coniferous tree species. Development of symptoms usually progresses this way: reduced growth and marginal yellowing, browning of the leaves, premature fall coloration, and premature leaf drop (Holmes 1961; Holmes and Baker 1966; Sucoff 1975). Frequently only the leaves facing the road are affected. According to Sucoff (1975), this is the most specific symptom and the one most easily used for diagnosis. Leaf drop often precedes twig dieback, which can be followed by dieback of entire branches and finally by tree death. In many cases, damage develops progressively over a number of years with continued winter salting (Sucoff 1975). For diagnostic purposes, these visual symptoms should be combined with analysis of leaf Na and Cl and analysis of salt in soil by conductivity (measured in mmhos/cm) and "exchangeable sodium percentage" (ESP), the percentage of the total cation exchange capacity occupied by Na.

GENETIC SOLUTIONS TO THE PROBLEM

Genetic Evaluation

One solution to the problem is to select and use salt-tolerant trees. Salt tolerance varies considerably among species and to a lesser extent within species (Demeritt 1973; Dochinger and Townsend 1979). Dirr (1976) emphasizes that the aim of any evaluation program should be to identify plants with partial resistance rather than total immunity, because no plants are wholly immune to salt injury. Generally, trees tolerant to soil-salt accumulation are able to adapt to salt because they have the ability to: (1) absorb and conserve water under salt stress, (2) exclude salt ion uptake, or (3) physiologically tolerate the presence of the salt ion.

Tables ranking species for salt tolerance have been developed by many authors (Blaser 1976; Carpenter 1970; Dirr 1976; Hanes *et al.* 1970; Monk and Wiebe 1961; Monk and Peterson 1962; Pellett 1972; Shortle and Rich 1970; and Sucoff 1975). Many of these rankings are based on insufficient data, and comparisons lack systematic experimental bases (Dirr 1976). As a result, authors vary in the relative tolerance they give to a species. As Dirr (1974) points out, good experimental techniques are necessary to compare species, progenies, or clones, and the evaluation must include consideration of salts, concentrations, application methods (soil versus aerial application), and both osmotic and specific ion effects. For example, tolerance to salt spray does not imply or necessarily correlate with tolerance to soil salt, or vice versa. Many criteria, not just visual injury, should be used in evaluating the response of trees to salt.

Studies at the Delaware Lab

Realizing the need for more thorough experimental work, we have carried out a series of studies designed to compare important or potentially useful urban species for tolerance to salt-spray and soil salt.

Our first study showed differences among three red maple progenies in response to salt (Dochinger and Townsend 1979). Our second study involved the comparison of six frequently planted urban tree species for which little information on tolerance to soil salt was available. The six species were white flowering dogwood (Cornus florida L.), American sycamore (Platanus occidentalis L.), pin oak (Quercus palustris Muenchh.), eastern white pine (Pinus strobus L.), Japanese pagoda tree (Sophora japonica L.) and ginkgo (Ginkgo biloba L.). A seventh species, honeylocust (Gleditsia triacanthos L.), was included in the study as a "standard" salt-tolerant species. Seedlings from the seven species were subjected to 0, 2000, 4500, and 7000 ppm NaCl in a hydroponics system for 5 weeks. To measure the total response to salt, we estimated foliar injury and measured reduction in height growth and dry matter production, and changes in Na, Cl, and essential elements.

Ginkgo seedlings did not grow well, even in the nutrient solution without NaCl, because pustules formed on the roots; their data therefore were not used in the analysis. Results from the other species indicated the importance of using several parameters to identify trees tolerant to salt. Dogwood and sycamore showed the greatest amount of foliar injury, high levels of leaf and stem Cl, and significant reductions in height growth and dry matter production. Pin oak and white pine were somewhat intermediate in their responses. Pin oak showed a high degree of foliar damage (similar to that of dogwood and sycamore) and high stem Na and Cl levels, but height growth and dry matter production were not affected. White pine showed low foliar symptoms and no reduction of height growth, but its dry weight production was reduced. Japanese pagoda tree and honeylocust showed the least foliar symptoms and no reduction in height or dry weight. The low foliar symptoms in the pagoda tree occurred espite high leaf Cl levels. Apparently low salt damage in this species is due to a physiological tolerance to high ion levels rather than to ion exclusion.

Changes in concentrations of essential nutritional elements (N,P,K, Ca, Mg,Mn,Fe,B,Cu,Zn,Mo) occurred in response to salt, but generally these changes did not indicate salt sensitivity. For example, the salt-tolerant honeylocust showed more decreases in elemental concentrations than did the salt-sensitive dogwood. The only elemental changes that appeared to be related to salt-tolerance were those in manganese and copper. The concentration of both of these elements increased in the leaves and stems of the salt sensitive species but remained stable in the tolerant species.

In another study we grew these species in either a silt loam soil or in a mix of peat:perlite:sand rather than in a hydroponics solution. Preliminary analysis of data indicates that response to salt and degree of salt tolerance is similar in soil and in a hydroponics medium. Screening of genotypes in the hydroponics solution therefore may be a reliable indication of their relative tolerance in soil.

Selection and Breeding

Selection and breeding for salt tolerant clones, progenies, and cultivars can be concentrated on families and genera that already possess a reasonable level of salt tolerance (Dirr 1976). For commercially valuable species that are somewhat salt sensitive, however, any genetic increase in salt tolerance can be justified. The salt-tolerance in all groups can be improved by screening populations, full-sib and half-sib families, and clones and then crossing the best biotypes. Release of clones or genetically identified, superior progenies is the ultimate goal.

The efficiency of any evaluation or selection and breeding program for salt tolerance depends on finding resistance mechanisms (Mass and Hoffman 1977). Dirr (1976) has evidence that the degree of salt tolerance in many woody plants depends on their ability to exclude Cl, and possibly Na, from entering cells. This ability is also a factor in salt tolerance of some agronomic species. For example, restricted uptake of Cl into leaves and stems of salt tolerant soybean cultivars is controlled by a single dominant gene (Abel 1969). In citrus, restriction of Cl movement into leaves is controlled by several genes acting quantitatively (Shannon 1979). Other genotypes may not exclude the ions but may tolerate the presence of such ions or may be more efficient in adjusting to the osmotic effects of salt. Unfortunately, no reliable and rapid screening technique for salt tolerance is known, either in trees or in agronomic crops (Shannon 1979).

Many factors must be taken into account in identifying trees with salt tolerance. Salt tolerance of agronomic genotypes partially depends on their stage of development (age) and partially on humidity, temperature, light, soil fertility, cultural practices, and presence of other stresses such as air pollution (Shannon 1979). These factors are probably important with trees, and therefore should be investigated.

Any evaluation or breeding program should be followed by field-testing of trees found to have salt tolerance in the greenhouse and laboratory. Trees should be planted where salt is a primary problem, such as city streets, highways, and freeway interchanges. Vigor, survival, and resistance to salt can be observed at periodic intervals after planting.

Research Needs

Identifying trees tolerant to soil salt first necessitates the development and use of systematic experimental procedures to compare different genotypes under the same conditions. Second, we must search for reliable markers for resistance, including physiological, biochemical, and morphological characteristics, that will enable us to distinguish a salt-resistant genotype from a salt-sensitive one of the same species. Third, we should determine the extent of juvenile - mature correlations of salt tolerance in order to measure the change, if any,

in relative salt tolerance from the seedling stage of development to maturity. Fourth, we must learn about the interaction with soil salt of other abiotic and biotic stresses such as air pollution, drought, soil compaction, fungi, bacteria, and viruses. This composite of stresses can be studied by comparing trees under relatively controlled conditions in the growth chamber and greenhouse. These comparisons should then be followed by the ultimate test, performance and survival along the street or highway.

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247 THE IMPACT OF URBAN SOILS ON VEGETATION[1]

by J. C. Patterson, research agronomist, Ecological Services Lab., National Park Service, Washington, D.C. 20242

J. J. Murray, research agronomist, Science and Education Administration, U. S. Dept. of Agriculture, Beltsville, Maryland 20705

J. R. Short, biological laboratory technician - soils Ecological Services Lab., National Park Service, Washington, D.C. 20242

ABSTRACT.--Urban soils can have a dramatic effect upon urban vegetative plantings. It is felt that 80% of urban vegetation problems can be traced to and/or caused by a poor soil environment. Topics to be discussed are the mapping of urban soils, compaction, characteristics of urban soils, and methods of dealing with stressed situations.

Experience gained working with the urban stress situation in Washington, D.C. and other sites has led us to project that about 80% of urban plant problems which develop can be initially traced to and/or caused by a poor soil environment. This poor environment renders a plant or planting susceptible to the synergistic effects of other dehabilitating urban stress factors producing an overall decline in plant vigor. If in fact this observation is valid, then it illustrates a severely neglected environmental condition. Further, the nurserymen's contention supporting "the $1 tree in a $10 planting hole" takes on some validity. For any urban planting site, the dollars must be available to accomplish the prescribed soil amendment activities. It cannot be overstated that we as urban plantsmen and greenspace engineers must be directly involved in the initial design and planning phases for all proposed planting sites in which vegetation becomes an integral part of that design. This is not to say that due to involvement, all of the plantings will be

[1]Metro. Tree Impr. Alliance (METRIA) Proc. 3:33-56, 1980.

successful, rather that a large majority of these sites will likely achieve their ultimate design concept. Secondly, at all activity sites, on site evaluations are imperative and contract change orders may be warranted as work progresses. Certainly it becomes frustrating when your task is simply to address the problem of what happened and what can be done to improve a poor situation. Recommendations which are directed toward the ultimate asthetics of the proposed planting must be "engineered" into the design concept and implemented as directed during construction.

Extensive work in Washington with urban soils and our cooperative work with the detailed Soil Survey of the District of Columbia (Smith et.al. 1976) has taught us many lessons and defined many of the major characteristics of urban soils. Over the years we have convinced traditional agronomists and others that: 1) there are soils existing within cities; 2) these soils have been neglected and concentrated efforts should be undertaken to understand them; 3) major physical and chemical characteristics of these soils have been verified (Patterson, 1976; Smith et.al. 1976; Stein 1978); 4) urban produced organic "wastes" can be recycled back into these soils as organic soil amendments either reducing or totally eliminating the need to purchase "topsoil" and peat moss-like materials (Cook et.al. 1979; Hammerschlag & Patterson 1978; Hornick et.al. 1979; Murray et.al. 1979 & 1980; Patterson 1975; Patterson & Short 1976; and Short & Patterson 1976); 5) these modified soils can and will provide support and nutrients for urban landscape plantings (Cook et.al. 1979; Hammerschlag & Patterson 1978; Murray 1980; and Patterson 1975); and 6) these organic materials can be highly beneficial with regard to maintenance of the plantings (Cook et.al. 1979; Hammerschlag & Patterson 1978; and Patterson 1975).

Mapping Urban Soil

The Soil Survey of the District of Columbia has illustrated that we can map urban soils and soil types with a great deal of reliability (scale 1" = 12,000') (Smith et.al. 1976). Even though the soils may not be completely identified with their natural counterparts, much can be inferred from observed mapping units or complexes with regard to utilizing existing soil information. Geographical distribution of soil types extend into urban centers. In some cases a soil scientist can delineate individual soil series with a high degree of accuracy. More commonly however is the observance of two or three soil series which have been intermixed by man's activities. This trait does yield some complexity with regard to interpretations, but, being able to recognize a mix of two or three soil series does provide a wealth of detailed soil information from which many sound judgements can be made. The ultimate extreme is the heterogeneous mixture of numerous soil materials or urban land complexes. This occurrence creates the most difficult management situation in that interpretations may need to vary extensively from planting situation to planting situation, even over very short distances. However, if these urban land complexes are mapped, and in the mapping unit description some reference is made to the predominant soil series which makes up the complex, there is a wealth of basic information already available. Further field observations are necessary to confirm the degree of complexity and ultimately to determine the best method to handle the proposed planting. Soils information in addition to the knowledge of plant types and their soil requirements will mesh into a picture of how best to perform the vital soil preparation work.

Presence of heterogeneous soil complexes necessitates extensive planning and anticipation of problems. Experience has dictated that the best soil

preparation method for urban land complexes is to achieve soil homogeneity over the site. Homogeneity of the soil mantle is a valued objective where urban plant requirements are similar. The implication is clear, the soil planting medium must be "engineered" into the urban planting site.

Another extremely valuable source of information is the historical records for that site. Knowing the original landscape, presence or lack of high water tables, etc. provides valuable resource information (Patterson 1975).

During the planning processes the topic of topsoil often arises. What is topsoil? Within the urban system, topsoil is the soil-like material which occupies the soil surface. Topsoil is a dubious term and the commodity itself is more so. Experience has suggested that the best method of obtaining topsoil is to manufacture it from urban soil and organic resources. Purchased topsoil nearly always requires extensive modification to meet plant requirements. These modifications may include sterilization, stone removal, fertilizer additions, organic matter additions, debris removal, liming agent additions, etc. Much success has been realized in Washington utilizing urban produced organics to amend existing urban soils to produce a fertile soil mantle economically (Cook et.al 1979; Hammerschlag and Patterson 1978; and Patterson 1975).

Composted sewage sludge has been used extensively in Washington, D.C. as a major soil amendment, top dressing mix, for potting mixes and many other uses. Although nutrient analyses of U.S.D.A. compost are generally low (Table 1), its value is considerable with regard to amending soil physical properties (Table 2) and the soil chemistry is generally enhanced (Table 3) (Murray et.al. 1980).

Table 1 represents what is considered a good sludge for many uses.

Table 1 Composition of sewage sludge compost used in studies at Beltsville, Maryland[1]

Property	Raw Sludge Compost	Property	Raw Sludge Compost
pH	7.3	Zinc	770 ppm
Total, Nitrogen	1.38%	Copper	300 ppm
NH_4, Nitrogen	0.02%	Nickel	300 ppm
Phosphorous	1.57%	Cadmium	10 ppm
Potassium	0.16%	Lead	290 ppm
Calcium	1.42%	Manganese	480 ppm
Magnesium	1.73%	Cd/Zn	1.3%
Organic carbon	23.0%	Sol. Salts	3.28mmho/cm

[1]Values based on several analyses of sludge from the Blue Plains Treatment Plant composted at the Beltsville composting site. Percentages are on a dry weight basis. Compost screened using 1.58 cm mesh screen. Murray, et.al. (1979).

Table 2 Effects of composted sewage sludge additions on soil moisture content[1]

Treatments Dry mT/ha	Soil moisture - % by weight April 22	July 28	August 3
0	17 b	12 b	11 b
50	23 ab	16 ab	15 ab
100	23 ab	16 ab	17 a
200	26 a	19 a	19 a

[1]Samples were taken from tall fescue plots growing on a sandy loam soil about 2 years after treatments were applied. Means within columns followed by the same letter are not significantly different (0.05 level DMR). Moisture content near field capacity on April 22. Control plots showing moisture stress on July 28. August 3 all plots were showing moisture stress symptoms. Murray, et.al. (1979).

Table 3 Effects of composted sewage sludge additions on soil, pH, cation exchange capacity, and organic matter content[1]

Compost mT/ha	Silt Loam Subsoil pH	Silt Loam Subsoil CEC	Silt Loam Subsoil O.M%	Sandy Loam Soil pH	Sandy Loam Soil CEC	Sandy Loam Soil O.M%
50	5.6	6.0	2.1	6.1	10	3.1
100	6.7	6.7	2.4	6.5	12	3.1
200	6.5	8.3	3.3	6.4	11	4.1
Fertilizers (AV)	6.3	4.2	1.7	5.9	10	3.0
Control	4.4	5.0	0.9	6.3	10	2.8

[1]Compost treatments were incorporated with the top 10-15 cm soil. Samples were taken for analysis approximately 2 years after compost treatments were applied. Values are averages of 3 samples from 6 replications of Kentucky bluegrass and tall fescue turf plots. Murray, et.al. (1979)

Composting of this material produces a nearly sterile organic amendment with relatively few problems. In general, the soluble salt content is elevated and the potassium and phosphorous levels are somewhat low; however, each of these parameters are easily altered.

Compost can and does produce a marked positive effect upon the moisture holding capability of urban soils (Table 2). Therefore, better rooting of plants has been characteristically observed with turf and other plants. Nursery studies are indicating more vigorous growth of potted plants and some nurseries are tending to favor use of compost over peat moss. A recent symposium focused on the utilization of these kinds of materials for production of Horticultural Crops. (Americal Society for Horticultural Science, 1980).

From the soil chemistry aspect there is an increase in pH, cation exchange capacity and organic matter percentage of the top 10-15 cm. of soil (Table 3). Each of these increases will provide added soil benefits to urban plantings and continue the philosophy of recycling urban produced organic soil amendments through urban soils (Cook 1979; Patterson 1976; Patterson & Henderlong 1970; and Patterson, 1975). The vehicle used to produce compost has been well defined elsewhere and the reader is referred to the literature (Epstein et.al. 1976; Patterson & Short 1976).

Compaction

Soil compaction is perhaps the most vivid and severely limiting factor associated with urban soils and yet it goes unheeded by many urban plantsmen. Compaction can deal a harsh blow to any urban planting (Hall 1979; Young & Gilmore 1976; and Zisa et.al. 1979). Anyone associated with urban vegetation should attempt excavating a planting hole in an urban site, it is a blister

raising experience. What is compaction and what are its effects upon urban vegetation?

Soil compaction is an integrated highly complex problem. Urban plantsmen must make sound judgements of how to deal with it. There are perhaps three important questions which must be addressed early in the planning phase: how many people will the site be expected to support; what is the intended use and desired effect for the site; and finally, how will the urban plantsman deal with soil compaction?

We as greenspace engineers have the task of maintaining an attractive and vigorous planting, and generally little say about visitation and its related impacts; therefore, we must have significant input with regard to the question of compaction during planning operations. Soil compostion and its measurement barometer - bulk density - is the laboratory tool used to quantify the degree of soil compaction. Normal or ideal soil bulk densities range between 1.30 and 1.40 g/cc. A soil bulk density in excess of 1.60 is considered compact and many urban soils in Washington greatly exceed this density; the same is true for other cities.

Further, subjecting the bulk density and particle density (normally 2.65 g/cc) to a simple calculation yields a measure of total pore space for a soil.* The total percent pore space for a "normal or ideal" soil is about 45% or more; however, we have commonly observed pore space percentages of 35% and less (Table 4 and 5; and Figure 1). In table 4 it is interesting to compare the total pore space for the "forested" <u>vs</u> "urban forested" soils presented. Comparing the grand means of the two conditions, the result is a loss of about 270% pore space for the urban setting. This is not a wholly valid comparison;

$$*\%\text{Pore space} = \left(1 - \frac{\text{Bulk density}}{\text{particle density}}\right) 100$$

TABLE 4

TITLE: COMPARATIVE SOIL PHYSICAL PARAMETERS OF A FOREST SOIL VS AN URBAN "FOREST" SOIL

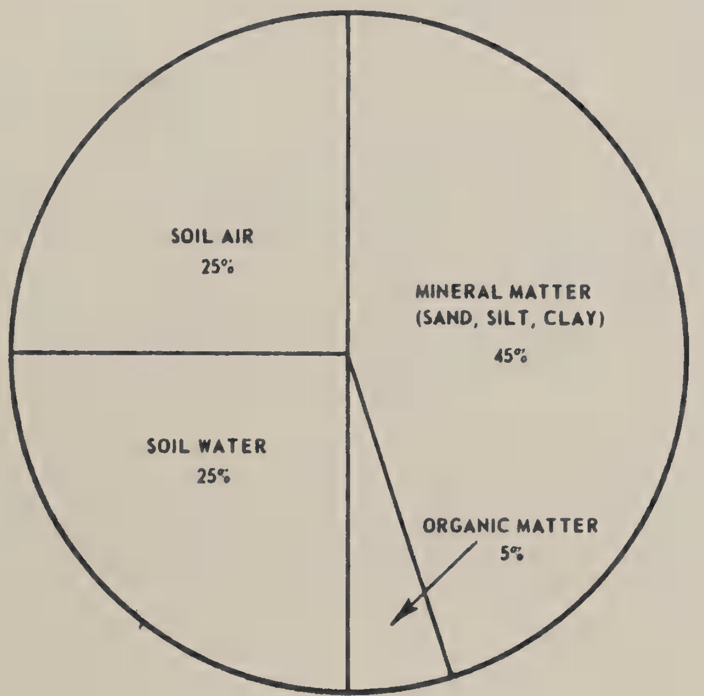
FORESTED PROFILES								URBAN "FORESTED PROFILES"							
Soil Type	Profile Depth (cm)	Sand (pct)	Silt (pct)	Clay (pct)	Bulk Density (g/cc)	Particle Density (g/cc)	Total Pore Space (%)	Soil Type	Profile Depth (cm)	Sand (pct)	Silt (pct)	Clay (pct)	Bulk Density (g/cc)	Particle Density (g/cc)	Total Pore Space (pct)
ASH LOAM	0-15	62.0	29.7	8.3	1.26	2.65	47.55	UDORTHENTS (MAN-MADE) (S71-DC-1-2)	10-15	29.8	53.1	17.0	2.12	2.56	17.2
	23-46	63.45	22.7	13.7	1.58	2.65	59.6		28-81	41.5	34.25	24.2	1.98	2.54	23.2
	58-94	75.7	14.6	9.7	1.79	2.65	67.55		81+	59.6	25.6	14.8	2.18	2.59	19.7
$\bar{X}$							58.23								21.0
MANOR LOAM	0-10	51.6	33.9	14.5	1.23	2.65	46.4	UDORTHENTS (MAN-MADE) (S71-DC-1-2)	0-23	32.0	46.0	22.0	2.08	2.40	13.3
	30-46	52.8	24.6	22.6	1.44	2.65	54.3		23-58	40.0	26.0	34.0	1.81	2.47	26.7
	56-79	76.4	13.5	10.1	1.49	2.65	56.2		76+	38.0	32.0	30.0	2.00	2.42	21.9
$\bar{X}$							52.3								20.6
$\bar{\bar{X}}$							55.26								20.35

Source: Smith, et.al. 1976; and Patterson 1976.

Table 5 Bulk and particle densities of selected soils sampled in the mapping study.

Pedon	Depth	Densities Bulk	Densities Particles	Pore Space
	cm	-----------g/cc	------------	(pct.)
1	0-23	1.41	2.61	45.98
	23-46	1.34	2.62	48.85
	46-71	1.37	2.62	47.71
	71-124	1.34	2.63	49.05
	124-165	1.33	2.65	49.81
$\overline{X}$				48.28
4	0-11		2.56	
	11-15	2.12	2.56	17.19
	15-29	1.81	2.65	31.70
	29-38	2.02	2.54	20.47
	38-81	1.95	2.54	23.23
$\overline{X}$				23.15

Stein. 1978.



A schematic representation of ideal soil composition.

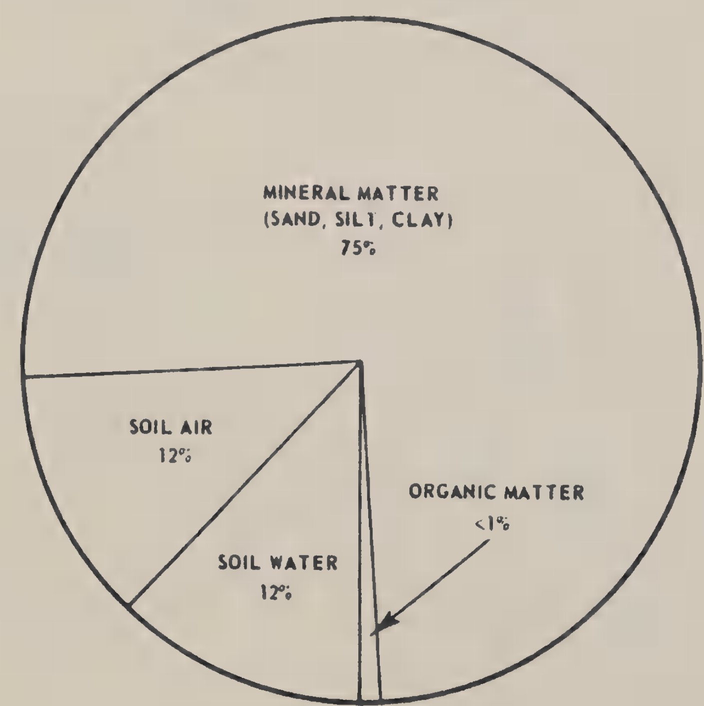


Diagram showing the generalized composition of a compacted soil.

FIGURE 1.

however, it does indicate a strong difference between a forest soil and an urban soil. Are urban soils as dense as concrete? In 1975 we conducted an experiment to determine the density and pore space relationships of four commonly used urban building materials: cinder block, brick, asphalt and concrete (Table 6). Comparing the results of this study vs some of the data presented in Tables 4 and 5 yields the interesting finding that, urban soils can be as dense as concrete and more dense than cinder block, brick and in some cases asphalt.

There are other deleterious effects of soil compaction. These effects although easily summarized can produce additional synergestic urban stress upon vegetation. Soil compaction can cause a reduction in 1) pore space; 2) total available moisture for plant growth; 3) moisture absorption, and; 4) oxygen content of the soil atmosphere. Conversely compaction serves to increase the thermal conductivity of the soil, increase runoff and erosion; increase the mechanical impedance of roots (i.e. a plant root must expend considerably more energy to penetrate the soil); increase hydrophobicity; and finally increase carbon dioxide content of the soil atmosphere.

Some recent thesis work (Stein 1978) undertook the task of Mapping, Classification an Characterization of Highly Man Influenced Soil in the District of Columbia. Two distinct soil systems were studied in detail: the first derived from dredged fill and the second was composed of miscellaneous urban fill (Table 5). Bulk density measurements of the two dramatically different soils indicated differences which were concluded to be due to their mode of deposition and basic textural differences. Also, some of these wide differences can be attributed to land use characteristics. However, this degree of difference appears to be more attributable to textural mode of deposition as in all cases the bulk densities of the miscellaneous fill

Table 6 Bulk density and pore space of four construction materials

Material	Number of samples	Bulk density Average	Bulk density Range	Particle density	Calculated pore space
		g/cc	g/cc	g/cc	percent
Cinder block	3	1.70	1.67-1.71	2.64	35.6
Brick	3	1.75	1.43-2.01	2.72	35.7
Asphalt	3	2.19	2.17-2.22	2.35	6.8
Concrete	3	2.26	2.23-2.27	2.47	8.5

Source: Patterson, 1976

exceeded that of the dredgings (Stein 1978).

As a result of this detailed study some work has been generated on the taxonomic classification of urban soils, suggesting their inclusion in the overall soil taxonomy system (Fanning, et.al. 1978; Stein 1978). Ultimately it is hoped that urban soils and their sister soils of rural drastically disturbed sites (strip mines, etc.) will be included in the Soil Taxonomy (Soil Conservation Service).

Characteristics of Urban Soils

Over the years some distinctive characteristics of urban soils have been observed and documented. Effects of bulk density have been previously discussed. Other distinguishing characteristics of urban soils are:

1-The mapping unit Urban Land Complexes and those including two or more soil series exhibit soil heterogeneity across the landscape which necessitates on site soil evaluations prior to any development (Patterson 1976; Smith et.al. 1976; Stein 1978).

2-There are variable precentages of organic matter with depth in the soil profile. This characteristic is due to mode of deposition and perhaps to a lesser extent use of the landscape before or during deposition (Patterson 1976; Stein 1978).

3-Unoriented coarse fragment (rock, stones) with profile depth. This feature is likely related to depositional mode (Patterson 1976; Stein 1978).

4-Highly variable soil chemistry with depth and across the landscape. Stein's work illustrated high extractable Mg and showed variability in pH and extractable

K_2O with profiled depth. Extractable P_2O_5 was low in dredged soils and more variable in the loamy fill soils. Base saturation was generally greater than 50% for both soils and nearly always exceeded 100% in soils developed in loamy fill (Stein 1978).

5-Textural differences are noted with profile depth. Generally profiles are characterized by lithologic discontinuities owing to depositional characteristics and origins of depositional materials. [Patterson 1976; Stein, 1978].

6-Urban oriented artifacts are common in many soil profiles, particularly the urban land complexes. Artifacts may include bits of concrete, brick, asphalt, cinder block, fragments of steel, china and glass pieces, etc. (Fanning, et.al. 1979; Patterson 1976; and Stein 1978).

7-Diagnostic soil color patterns have been observed with profile depths and landscape positions (Stein 1978).

8-Identifiable drainage classifications can be characterized from soil color patterns and topographic changes (Stein 1978).

9-There is a tendancy for the more highly compacted soils to exhibit a hydrophobic tendency. That is, when an event occurs producing any surface water, water droplets will tend to bead on the soil surface. Infiltration patterns into these soils have shown a lag phase initially until the surface tension of the soils is sufficiently reduced to allow water penetration. Once this penetration is initiated, the infiltration curves resemble those of natural soils although the intake rates and total infiltration rates are generally

much lower. Patterson (1976).

10-Compacted soils exhibit the characteristic "platy" structure when observed closely. This characteristic can also cause limited infiltration. Interestingly the platy structure can be observed in burned-over areas as well. Soils developed in the dredged areas exhibited prismatic structure (Patterson 1976; Stein 1978).

11-Rooting patterns in compacted soils are equally interesting. Turfgrass roots are observed following natural cleavage planes within the soil profile and they are present in these fractures in large numbers. Conversely, in more friable soils, roots are well distributed throughout the soil mantle. Tree roots may or may not be confined, depending upon the degree of compaction and other characteristics (Patterson 1976).

12-In highly compacted soils, earthworm activity is less apparent owing presumably to the degree of compaction. (Patterson 1976; Stein 1978).

13-Soil taxonomy is a difficult area and most urban mapping units fall into the broad high category, Entisol-Inceptisol subgroups. However, many of the complexes observed in Stein's work were classified as Udorthents following the D.C. Soil Survey. Much work needs to be accomplished with regard to urban soil taxonomy. Generally, to estimate the mean within $\pm$ 10% with a 95% C.I., the most variable properties within mapping units required between 100 and 700 samples, for example, morphological properties. The least variable properties generally required less than 25 samples for estimation, such as the bulk

density of the second horizon (Stein 1978).

Avenues of Development

To date many recommendations can be generated from existing knowledge. It is essential to design an appropriate soil mantle for support of proposed urban planting. Recommendations must be set forth and observed if any urban planting is to be successful.

1-Planning and design of the soil mantle must be an integral part of the urban landscape design. Most if not all plants, once in place in the landscape, are expected to exist for 10 or more years. Key to this existence is the fact that once plants are in place, especially trees, the soil cannot be modified other than through surficial treatments; the root systems will not permit further modification and yet compaction can severely limit rooting (Patterson 1976; Zisa et.al. 1979).

2-Budget dollars must be included within the contract for the total urban planting-soils, plants, etc. The more stressed the situation, the more dollars must be budgeted.

3-Whenever possible within the urban stress situation, amend the soil mantle uniformly; e.g. the desired soil mantle is a homogeneous one. Similarily, when trees are included the minimum depth of modification is 45 cm., turf areas 15 cm. There are many different materials which can be used to physically amend a soil in addition to those organic composts already mentioned. Several of the more popular and effective inorganic soil amendments are sands (Daniel 1978; Davis 1973;

Patterson 1976), sintered fly ash (Patterson and Henderlong 1970; and Short and Patterson 1976), expanded slate (Patterson 1976; and Short and Patterson 1976) and many other similar materials. These particular materials are mentioned because they are moderately priced and effective over the long term.

4-Soil drainage systems for most areas are critical. A soil physics professor once said "you can always add water to a soil system, you cannot always remove it." Several methods exist with regard to subsurface drainage systems. These subsurface systems should be contoured parallel to the finished soil surface grade. These systems can be basic subsurface grading, tiling, flexible piping, etc.

5-At sites where traffic control (human or other) will be a continual problem and one severe enough to perhaps impose undue stress upon a planting, engineer the soil system to withstand the compactive forces. This planning must be continuously supplemented by proper soil aeration techniques performed during appropriate seasons. If impact will be such that plants will be continually stressed, perhaps paving of the soil surface is the best answer, while handling the plants as potted plants. There are available pavers which permit turfgrass growth, porous pavement, wood chips, and other similar materials.

6-Site maintenance will vary directly with the degree of traffic or use imposed upon the site.

7-Experience suggests that it's better to amend the existing soil removed from a planting hole than to place a "prepared

soil mix" around the tree ball. The implication is that by placing a prepared soil mix around the root ball, there exists three distinct soil physical situations: the ball itself vs the prepared soil mix vs the existing soil. Hasten to mention that this is a site dependent factor.

8-Utilize plant materials which are known to tolerate the urban stress situation i.e.: compaction, wetness, low oxygen, etc. Root systems are vital. An urban tree will never reach its mature crown form if its root system cannot cope with a stressed soil situation (Patterson 1976).

9-Beds of horticultural plants should be raised above surrounding grades such that they are perhaps 45 to 91 cm. above surrounding grades, this is particularily important for high water table situations. Mounding also provides a pleasing three-dimensional effect which with time becomes largely unnoticed (Hammerschlag and Patterson 1978).

10-Should trees be placed into a low topographic situation, a pedastal of existing soil should be left in the center of the planting hole to prevent the tree ball from subsiding below the soil surface. In general, trees should be planted from 10 to 20 cm. above surrounding grades (Hammerschlag and Patterson 1978).

11-Mulches should be avoided in areas where soil drainage and runoff is impared. These materials can exaggerate plant problems (Whitcomb 1979). Our own experience in Washington reflects this same observation. Plastic mulches should generally be avoided.

Summary

The effect of urban soils upon the success of vegetative plantings cannot be overemphasized. Urban soils are beginning to receive the attention needed to provide the knowledge for proper use of the soils. It has been found that urban soils can be mapped using recognized mapping units with an acceptable accuracy, although field verification is required.

The planning process must include consideration of soil conditions at the planting site which may limit plant growth, such as compaction, wetness, human and vehicular traffic, etc. Alleviation of many limiting soil properties may be effected through the use of compacted urban organic "waste" materials.

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DEVELOPING TREE VARIETIES FOR URBAN SOIL STRESSES[1]

by Kim C. Steiner, Associate Professor
School of Forest Resources
The Pennsylvania State University
University Park, PA 16802

ABSTRACT.-- The importance to trees of several types of soil stress (poor aeration, moisture deficiency, toxic metals, and low fertility) in the urban environment is briefly reviewed, and the possibilities for developing cultivars that are tolerant to each of these stresses are discussed. Five criteria are listed by which the practicality and potential success of meeting improvement goals can be assessed. In light of these criteria, tolerance to soil moisture deficiency and tolerance to low fertility are the most promising improvement goals. However, tolerance to soil moisture deficiency is difficult to evaluate in trees, and the need for tolerance to low fertility in urban areas has not yet been conclusively demonstrated.

COMPANIES THAT MANUFACTURE fertilizer spikes, nutrient capsules, nutrient injection systems, and other products for fertilizing trees do a thriving business with arborists and homeowners. When these treatments are used they frequently result in some increase in the health of the tree, suggesting that the tree was under some degree of stress before treatment. Stresses caused by poor nutrition and other soil characteristics are known to reduce the resistance of plants to diseases (Schoeneweiss 1973). A tree that is stressed--i.e., one that will respond with renewed vigor to a change in its environment--is not fully adapted to the conditions under which it is living and is a candidate for genetic improvement.

Soils in urban environments tend to have several characteristics that mav cause poor survival or growth of trees. They are often low in fertility because of a loss of organic matter or disruption of the soil profile. Deicing salts and heavy metals arising from vehicular

[1]Metro. Tree Impr. Alliance (METRIA) Proc. 3:57-69, 1980.

traffic and industrial processes may be present and may cause chemical toxicities. Soil compaction or the presence of pavement over the roots are almost ubiquitous in urban areas and contribute to anaerobic conditions by either reducing pore space in the soil or limiting gas exchange with the atmosphere. Re-grading around existing trees may result in the same problem by increasing the distance between tree roots and the atmosphere. Finally, urban planting sites are frequently drought-prone because of reduced infiltration of moisture, a condition which is often exacerbated by elevated leaf-surface temperatures and transpiration.

To improve the health of trees in urban habitats, we can modify the environments or we can improve adaptation to the environments by planting better varieties. Either approach may be the more practical in any particular situation, although it is always desirable to both plant the best varieties available and provide good cultural care to the trees. In the following pages, I want to focus on the genetic approach by discussing the potential for developing tree varieties that are tolerant to several soil stresses common in urban areas.

POOR SOIL AERATION

Of all soil stresses in urban areas, the most common may be poor aeration. Under anaerobic conditions, roots exhibit a decrease in water and nutrient absorption, tree vigor is reduced, the incidence of diseases may be increased, and the plant may eventually die. Causes of poor aeration include overlying pavement, the occasional addition of soil above the roots of existing trees, and soil compaction by pedestrians and vehicles (Patterson 1976, Yelenosky 1963). Patterson (1976) emphasized the importance of soil compaction in urban areas by proposing that soil bulk density is the best single indicator of soil conditions in areas of intense use.

Flooding also causes poor aeration in the soil. Although flooding is not common in urban areas, Yelenosky (1963) found that species differences in response to flooding were very similar to species differences in general performance in urban areas. As may be expected, species that inhabit bottomland sites are generally more tolerant of flooding than species that inhabit upland sites (Gill 1970). Considering the importance of poor soil aeration in urban habitats, it is probably no coincidence that most of the species of <u>large</u> trees commonly

planted along streets are native to bottomlands: pin oak, willow oak, honeylocust, green ash, red maple, silver maple, some of the lindens, sycamore or plane tree, sweetgum, and American elm.

Nothing is known about intraspecific variation in trees in tolerance to poor soil aeration, although evidence of genetic variation in rates of root respiration (Allen 1969) suggests that it may exist. It would probably be possible, but difficult, to develop varieties with superior tolerance to this trait. Yelenosky (1963) indicated considerable difficulty in arriving at consistent differences among species using different methods to effect anaerobic soil conditions. Presumably, it would be even more difficult to evaluate differences within species. Rankings reported by different authors for differences among species in flooding tolerance tend to be somewhat inconsistent, also, since response may vary with season of flooding, duration of flooding, and age of tree (Gill 1970). Breeding for this trait could perhaps be a fruitful and useful activity, but first a method must be developed by which response to poor aeration can be measured quickly and with consistent results.

SOIL MOISTURE DEFICIENCY

Several features of urban areas contribute to slightly higher temperatures compared to surrounding countryside (Andresen 1976) and to increased transpiration by trees. Runoff from paved surfaces presumably diminishes the amount of moisture that reaches the soil, although Patterson (1976) observed that soil beneath pavements is usually quite moist. Roberts (1976) proposed that insufficient moisture is one of the most common stresses on urban trees. Certainly, symptoms of drought injury, particularly leaf scorch, are common in late summer on some tree species in urban areas. Drought stress has been implicated as a predisposing factor in ash dieback (Tobiessen and Buchsbaum 1976) and other tree diseases (Parker 1969).

There is considerable evidence of genetic variation in drought resistance within native tree species. As expected, trees native to relatively dry habitats are generally more drought resistant than trees native to moist habitats (Bilan et al. 1977, Meuli and Shirley 1937, Townsend and Roberts 1973, and others). Habeck (1958) found that northern white-cedars from upland habitats had more plastic (adaptable?) root systems under varying soil moisture regimes than those from lowland habitats, although nothing was determined about drought

resistance *per se*. Thus, it may be possible to develop drought resistant varieties in at least some tree species. Paradoxically, there may already exist races of some species that are relatively tolerant of both flood and drought. Those species of eastern hardwoods whose ranges extend farthest into the Great Plains, where selection for drought resistance may be expected (Bey 1974, Meuli and Shirley 1937), are all inhabitants of bottomlands: green ash, hackberry, bur oak, eastern cottonwood, American elm, and boxelder. Each of these species has been classed as relatively tolerant of flooding (Bell 1974, Hall and Smith 1955), although this character, also, could vary from one part of the distribution to another.

Even if the genetic potential exists for developing drought-resistant varieties, there are practical difficulties in evaluating genetic variation in drought resistance. In particular, the relative response of *seedlings* to imposed drought can be influenced by differences in characteristics that may change with age or cultural practices. These include rooting depth, root/shoot ratio, leaf surface area, and root regenerating potential after transplanting. Bey (1974) found that seedlings of black walnut from relatively dry and moist provenances differed in time to wilting under imposed drought. However, these differences in apparent drought resistance were not correlated in the expected manner with survival and growth of the same provenances on a "droughty" upland site.

Kozlowski (1976) suggested breeding for small stomata, few stomata, stomata that close early during drought, abundant leaf waxes, or dwarfing rootstocks. These characteristics contribute to drought resistance and may not change appreciably with age or cultural conditions. In lieu of developing varieties specially selected for drought resistance, some improvement in resistance can probably be obtained by simply using provenances from relatively dry sites or regions in ecologically variable species such as red maple (Townsend and Roberts 1973) or geographically dispersed species such as green ash (Meuli and Shirley 1937) and sugar maple (Kriebel 1963).

TOXIC METALS

Elevated concentrations of certain heavy metals (lead, zinc, cadmium, and nickel) have been found in plant and soil samples taken from densely populated areas and transportation corridors (Lagerwerff and

Specht 1970, Motto *et al*. 1970, Smith 1973). Among these elements, lead (from gasoline combustion) usually appears in greatest concentrations, particularly near heavy traffic. All are toxic to plants (Foy *et al*. 1978).

Research on herbaceous plants (Antonovics *et al*. 1971) suggests that it would be possible to develop heavy-metal tolerant varieties of trees. Ecotypes tolerant of lead, zinc, or cadmium have frequently evolved in grasses and forbs that colonize mine tailings (Gregory and Bradshaw 1965, Hogan and Courtin 1977, Jowett 1964, McNeilly 1968, Simon 1977). However, on sites other than these, actual phytotoxic effects caused by ambient heavy-metal concentrations have been more difficult to demonstrate. Most metals are precipitated or bound in soils, thus reducing their availability to plants (Foy *et al*. 1978). Reports of elevated concentrations of heavy metals in soils along roadsides do not usually distinguish between "total" and "available" levels, nor do we know what effects these elevated concentrations have on plants (Smith 1975). Similarly, concentrations of heavy metals in plants growing in urban areas may be exaggerated by failure to remove particulate deposits on external surfaces (Motto *et al*. 1970, Smith 1973). However, Rolfe (1974) found that lead concentrations inside trees growing near heavily traveled roads had increased over several decades.

Persuasive reports of actual toxicity to roadside plants by heavy metals are rare. One of the best ways to demonstrate phytotoxicity *in situ*, where it is difficult to isolate a particular cause of plant response, is to show that the plants have evolved tolerance to the toxin to which they are believed to have been exposed. This was done by Wu and Antonovics (1976), who demonstrated that English plantain (*Plantago lanceolata*) had evolved a lead tolerant population immediately adjacent (0.5 meters) to Main Street in Durham, North Carolina. However, at distances as short as 4 meters from the road, the plantains exhibited the normal low level of tolerance, indicating that lead toxicity at that distance from the source of pollution was not severe enough to be effective in selection. Four meters is, of course, easily spanned by the shoot and root systems of trees, and many urban trees are not planted that close to the road. Thus, whatever significance one wishes to place on this single report, the importance of heavy metal toxicities to large woody plants in urban environments is still open to question. The present state of knowledge does not warrant any investment in developing heavy-metal tolerant tree varieties for urban areas. Future

revelations could change this, of course.

LOW FERTILITY

There is little information available on the nutritional status of urban soils compared with that of the native soils on which our common shade trees evolved. However, it is probable that urban soils are generally less fertile with respect to certain macronutrients, particularly nitrogen. Poorer fertility than the trees are accustomed to will contribute to nutrient stress. Whether or not foliar symptoms of deficiency are present, nutrient stress may contribute to disease and insect susceptibility--which can further detract from tree health.

Research on forest trees indicates that genetic variation in response to fertility levels is very common in tree species. Clones or families in several species have been shown to vary in response to nitrogen levels (Curlin 1967, Roberds *et al*. 1976), phosphorus levels (Mason and Pelham 1976), or some combination of these and other nutrients (Jahromi *et al*. 1976, Pritchett and Goddard 1967, Steinbeck 1971). Genetic variation in response to fertility appears to be more or less a local phenomenon in natural populations. While we expect to find cold-tolerant trees in the North, and drought-tolerant trees in dry regions, the geographic occurrence of tolerance to infertility in native trees is much less predictable. Fairly large differences in response are sometimes found even among trees growing near one another in a single wild population.

If it can be definitely shown that poor fertility is a chronic and widespread stress in urban trees, the development of tolerant varieties would be one of the most useful contributions that geneticists can make in urban tree improvement. Since stress tolerance and fast growth may actually be incompatible improvement objectives (Grime and Hunt 1975, Parsons 1968), urban tree breeders may find it easier to employ tolerance of infertility than forest tree breeders. The best measure of tolerance to infertility is probably relative growth at low *vs*. high nutrient levels, on the presumption that a minimal increase in growth with increasing fertility indicates minimal stress at low fertility (Steiner and McCormick 1979). The fact that maximum growth response is not of particular concern in urban trees could be a definite advantage in developing varieties that are better adapted to urban habitats (Zobel and Kellison 1978).

Some nutrient disorders of shade trees arise not from any failing in the urban environment *per se*, but from our attempts to plant some species on soils very different from those to which the trees are accustomed. For example, pin oak and several other species develop iron deficiency (Neely 1976) and some maples develop manganese deficiency (Kielbaso and Ottman 1976, Smith and Mitchell 1977) when these species are planted on alkaline soils. These particular deficiencies are frequent enough in shade trees that developing varieties specifically for resistance to them may be justifiable. Berrang and Steiner (1980) were successful in identifying pin oak families that were nearly as tolerant of iron chlorosis as two other oak species that are often used in lieu of pin oak on calcareous soils. Wallace and Lunt (1960) reported some evidence that sweetgum may also vary in resistance to iron chlorosis.

DISCUSSION AND SUMMARY

The practicality of developing cultivars with improved genetic response to urban stresses must be evaluated for each situation according to the following criteria:

1. *Need* -- Obviously, the stress must be an important one and the species widely planted.

2. *Genetic potential* -- Tolerant variants must be present in the species, and the amount of variation must be great enough to be of practical significance.

3. *Feasibility* -- It must be possible to identify tolerant variants without prolonged and elaborate procedures for testing and evaluation.

4. *Cultivar stability* -- Variants must exhibit stability in tolerance over a range of environments to avoid the necessity of developing different cultivars for different sets of conditions.

5. *Ease of propagation* -- If tolerant genotypes are not easily cloned, then seed propagation is necessary and long-term breeding may be required to obtain a cultivar that reproduces true to type.

The importance of these criteria may be illustrated by our experience at Penn State in trying to develop a

chlorosis-resistant pin oak cultivar. In this case, Criteria 1-3 were passed with flying colors. Pin oak is one of the most popular street tree species, and iron chlorosis is definitely a common problem. As mentioned above, there is a substantial amount of genetic variation in the species for resistance to chlorosis; and this variation is fairly easy to evaluate if the proper experimental conditions are used (Berrang and Steiner 1980). Since these criteria are the ones that tree breeders pay the most attention to, the prospects for developing an improved cultivar of this species appear excellent at first glance.

However, Criteria 4 and 5 present some difficulties that force us to be cautious (though not necessarily pessimistic) about the future success of this project. In the first place, we were able to evaluate chlorosis resistance only under a limited set of conditions. Many environmental factors are known to influence the severity of iron chlorosis, so we could not guarantee the superiority of a cultivar without rather extensive testing at many locations over many years. Would consumers plant a pin oak cultivar that was only possibly resistant on untried sites? --probably not. Secondly, we compared resistance among sets of progenies, yet the data also suggested considerable differences among individual trees. We can neither evaluate the resistance of individual genotypes, nor propagate superior ones, because of our inability to readily duplicate genotypes of pin oak with rooted cuttings. Developing varieties of pin oak that breed true for resistance could take decades. We can reproduce the families that proved to be superior, but would consumers accept seed-propagated trees that have only an average high level of resistance? Perhaps not, considering the importance and value of the individual tree in the urban landscape.

As illustrated by this example with pin oak, the potential of any improvement effort cannot be fully assessed until the effort has already begun and some of the necessary information has been obtained. Obviously, much depends on the biology and genetics of each species studied. However, our current knowledge suggests that developing adapted cultivars would generally be more practical for some types of soil stress than for others. This is summarized below by considering each of the stresses in light of the criteria that must be met in an improvement program. "Ease of propagation" is omitted, since this depends entirely on characteristics of individual species.

The need for tolerance to toxic metals in the

urban environment has yet to be shown to be important, so this improvement goal should presently receive low priority. However, if there were a need, other criteria would appear to be favorable: evidence from herbaceous plants indicates that the genetic potential for tolerance is present in many species, reliable methods are available for testing and evaluation, and tolerance to toxic metals has proven to be relatively stable over a range of environments.

Improved tolerance to poor soil aeration would probably be desirable in some species. However, the genetic potential for developing tolerant cultivars is unknown, and reasonably fast and reliable methods for testing and evaluating response to this stress have yet to be developed. The stability of tolerance to this stress must also be considered unknown, but we do know that species differences in tolerance appear to change with the seasonal timing and duration of poor soil aeration.

The performance of many species in urban environments would probably be helped by better tolerance to soil moisture deficiency. Variation in drought resistance is known to be present in many species. We still do not know enough about methods of testing and evaluating response to drought to be confident that results obtained with seedlings will be applicable to older trees. However, selecting for specific drought-avoidance adaptations could overcome this problem. Some drought-avoidance adaptations are very stable from one environment to the next. Thus, some effort toward developing drought-resistant cultivars is justified.

There is likely a need for tolerance to low fertility in many species planted in urban areas, although this has not been proven. The genetic potential for improved response to low fertility levels is known to be present in many species, and methods of testing and evaluation are relatively simple. The stability of tolerance to low fertility must be determined on a case-by-case basis since much depends on the chemistry and physiology of the nutrient in question and the genetics of the species. This could prove to be a productive area for research, but it is first necessary that more be learned about the urban soil environment so that specific breeding goals can be identified.

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Effect Of Transplant Method And Fertilizer Application On Growth Of *Acer rubrum* C. and *Fraxinus pennsylvanicum* L.[1]

By Robert E. Schutzki, Cooperative Extension Agent, Cooperative Extension Service, Cook College, Rutgers, the State University, New Brunswick, New Jersey 08903

ABSTRACT.--*Acer rubrum L.* 'October Glory' (red maple) and *Fraxinus* pennsylvanicum L. 'Marshall Seedless' (green ash) were planted in an asphalt parking lot using standard horticultural practices with a factorial combination of treatments that included two planting stocks (bare-root and balled and burlapped) and two fertilizer levels (a control and 1.36 kg of 10-10-10 fertilizer along with 1.36 kg dolomitic limestone per tree.) After two years BR red maple growth was generally greater than for height growth; and shoot growth of fertilized BR trees was much greater than shoot growth of any other red maple treatment. Among the green ash treatments, control BR trees grew better than B&B trees. The fertilization depressed growth of BR green ash and there were no significant differences between growth of fertilized BR and B&B trees.

Recent attention has been focused on the parking lot as a major cause of urban blight. Thermal discomfort, rapid water run off and pollution load are a few types of problems created by vast impervious asphalt surfaces asphalt surfaces (Robinette, 1978.) Trees planted within a parking lot have the potential of ameliorating these deleterious conditions (Heisler, 1974.) Microclimatic changes, changes in quality and quantity of water runoff (Pham, 1978,) will not be drastically altered immediately after the introduction of trees, but these benefits should increase as the canopies of these trees expand over the years. It is axiomatic that these trees must survive and thrive if they are going to produce ameliorating effects, but the parking lot environment creates a number of stress conditions that could adversely effect both survival and growth rate.

Little is known concerning growth and development of shade trees introduced into the urban environment. Few statistically designed research efforts have been conducted to study species adaptability, planting techniques, nutrient needs, survival and growth rate of trees planted in the stressed condition.

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[1]Metro. Tree Impr. Alliance (METRIA) Proc. 3:70-76, 1980.

The objectives of this study were to compare the survival and growth rate of the two shade tree species, Acer rubrum L. and Fraxinus pennsylvanicum L., planted in the asphalt parking lot; to compare the handling methods of bare root versus balled and burlapped; and to evaluate the effects of adding fertilizer at the time of planting trees in disturbed soil. The results will be used to aid in developing guidelines for urban and suburban communities for the introduction of shade trees into their physical environment. These guidelines seek to improve the physical quality and enhance the esthetic properties of our communities through the selected use of plant material.

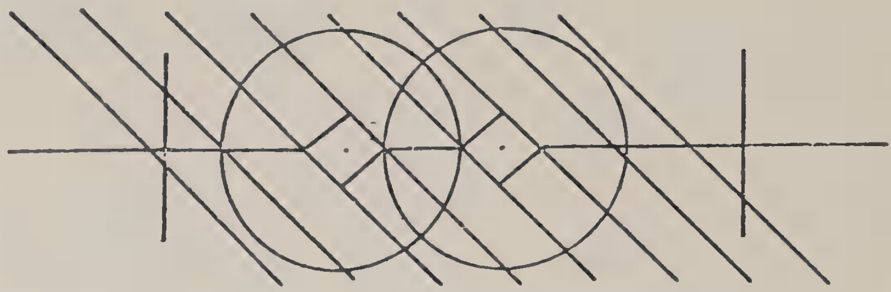
MATERIALS AND METHODS

The parking lot chosen for this study is located on the campus of Cook College, Rutgers University, No. 98. It is 191 m long and 50 m wide wide, encompassing an area of 0.966 hectare (2.39 acres.) The lot was constructed on an area of poorly drained Nixon series soil.

The planting sites were established in the parking lot utilizing a diamond pattern (Fig 1., Nelson, Porter 1976.) The sites were constructed by excavating a 5.4 m^2 area of pavement to a depth of approximately 45 cm. Four railroad ties were permanently enclosed around the planting hole to act as curbing. The planting hold was then filled with planting soil to approximately 15 cm above the asphalt level. The planting soil came from the 20-84 cm layer excavated during construction of the lot in 1972. Thirty two planting sites were located on the lot, allowing a ratio of one tree per ten parking stalls, leaving approximately 18 m between trees.

Sixteen Acer rubrum L., 'October Glory' and 16 Fraxinus pennsylvanicum L. 'Marshall's Seedless were purchased from a local nursery. The trees' caliber were 3.0-4.0 cm at 30 cm above the soil line. Half of the trees of each species were balled and burlapped and half were bare-root.

The trees were planted on April 23, 1976 according to standard nursery practices. Pruning was performed by following guidelines established by New Jersey Federation of Shade Tree Commission.



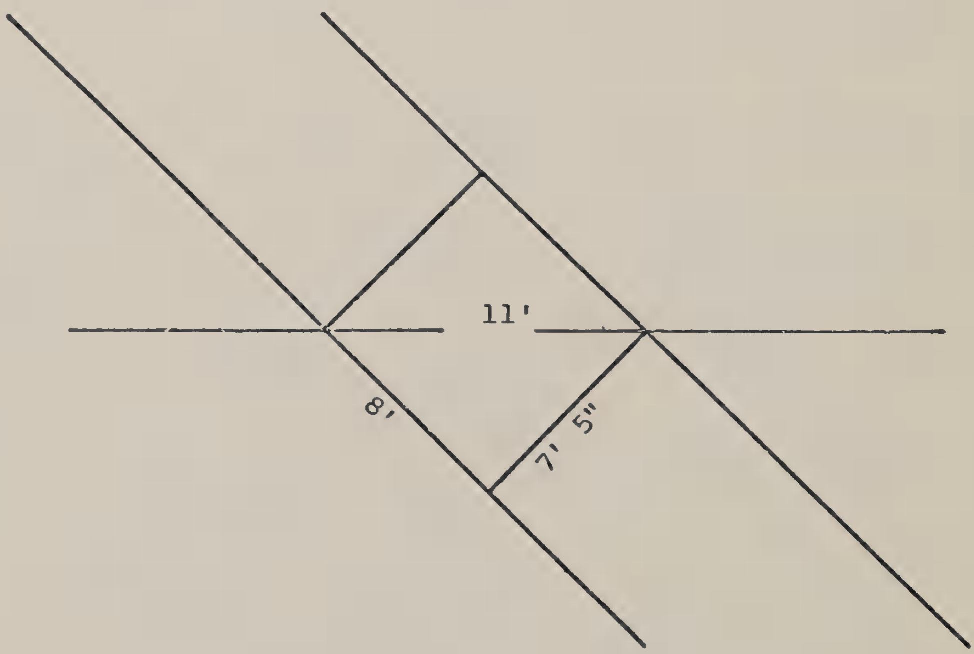


Fig. 1. Diamond planter pattern used within the diagonal parking stalls on Cook College parking lot #9B.

The fertilization and lime treatment within the project consisted of an application of a complete inorganic fertilizer (grade 10-10-10) and the addition of pulverized dolomitic limestone (min. $CaCO_3$ 51.5%, min. $MgCO_3$ 44.0%) versus no additional soil amendments.

The soil amendments were based on a nutritional study conducted by Dr. Pham Chuong prior to the beginning of this project (Pham, 1978.)

Dr. Pham Chuong related the existing nutrient status of the planting soil with acquired results based on growth responses from the nutritional study and calculated the treatment rate to be: 1.36 kg of the pulverized limestone.

The soil amendments were hand mixed in the appropriate planting site with approximately 0.3 m^3 of planting soil. Mixing took place immediately prior to the planting of each of the treated sites.

Data collection extended over two complete growing seasons (April 1976 - December 1977.) All measurements were taken in the dormant period following the growing season (December 1976 - December 1977.) All growth parameters monitored during the course of the study were analyzed statistically to determine significant treatment differences by an analysis of variance. Duncan's multiple range at the .05 level were determined for each significant test.

Total tree height was measured from a permanently established point at the soil line. The annual height increment was determined by calculating the difference in total tree height between measurements taken at the end of each growing season. Initial tree height was taken when the trees were planted.

Shoot growth was monitored on six shoots per tree. Three shoots of similar diameter were chosen from the north and south side of the tree. The branches were selected from the mid crown and permanently tagged.

RESULTS

All of the trees survived the first two growing seasons. Growth the first season was generally much less than the second season by any measure for all treatments.

Analysis of variance for each of the growth responses with year added to the factors species, stock, and fertilizer showed significant interactions between the main effects. Further, the variances of the two species differed considerably, as did the variances of the two years. Hence, mean separation for each growth response was done by four separate analyses of the four treatments within each species and year group (Table 1.)

During the first growing season no significant differences in shoot growth were formed between control and fertilized B&B green ash. Shoot growth in BR decreased by fertilization. Fertilization during the second season continued to decrease shoot growth in the BR trees, whereas fertilization had no effect on the B&B green ash trees.

Shoot growth on BR red maple was increased by fertilization during the first growing season. There were no differences found during the second season, however, fertilization increased total shoot growth in the BR red maples over the two year period. This significant differences in annual or total shoot growth were found between B&B control and fertilized red maples during the two year test period.

Fertilization decreased height growth on BR green ash the first growing season. There were no significant differences found between the B&B green ash trees, nor in either the BR or B&B green ash during the second growing season.

CONCLUSION

The intitial establishment of green ash and red maple trees planted within the parking lot was 100% successful. Despite the potential stress of the parking lot environment, all trees survived the critical first two years following transplanting.

The fertilizer treatment response observed suggests that the reaction to fertilizer applied at transplanting is species dependent. The marked increases in shoot growth the first season and total shoot growth in BR red maple in response to the fertilizer treatment suggests that the addition of fertilizer at transplanting may be beneficial for red maple growth. On the other hand, fertilizer applied to the backfill for BR green ash decreased growth suggesting that BR green ash may be particularly susceptible to possible fertilizer injury. The ability of bare-rooted trees to utilize the inherent and added fertility of the backfill, presumably because of the fact that the feeder root system would have had to develop in the backfill, may also offer an explanation for the general increased growth observed in the BR trees compared to B&B trees.

Table 1.--Summary of treatment means and mean separation analysis. Within each group of four means for a given year and species combination, means with the same letter superscript or letter are not significantly different.

	SHOOT GROWTH cm			HEIGHT GROWTH cm		
Treatment	FIRST YEAR	SECOND YEAR	SUMMARY	FIRST YEAR	SECOND YEAR	SUMMARY
Red Maple						
B&B, Control	3	36^{a}	38	8^{a}	66	73^{ab}
B&B, Fertilized	3	45^{ab}	48	8^{a}	61	68^{b}
BR, Control	18	138^{bc}	155^{a}	18^{b}	103	121^{a}
BR, Fertilized	58^{a}	194^{c}	252^{b}	22^{b}	69	91^{ab}
Green ash						
B&B, Control	9	16^{a}	25^{a}	16	41	58^{a}
B&B, Fertilized	11	52^{ab}	62^{ab}	13	81	94^{ab}
BR, Control	20^{a}	88^{b}	108^{b}	26^{a}	86	112^{b}
BR, Fertilized	9	37^{a}	46^{a}	16	45	61^{a}

The ability of the trees in this experiment to survive and grow satisfactorily in the parking lot is undoubtedly the result of the modification of the planting site. Further research is needed to privide additional information on planting site specifications to improve the establishment of trees in our urban areas.

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POTENTIAL BENEFITS OF MYCORRHIZAE IN THE URBAN ENVIRONMENT [1]

by Larry J. Kuhns, ornamental horticulture extension specialist, The Pennsylvania State University, University Park, Pennsylvania 16802

ABSTRACT.--Trees colonized by selected mycorrhizae-forming fungi may benefit in a variety of ways from the resulting association. These potential benefits, and the steps which must be followed to achieve them, are described.

Certain fungi are capable of infecting roots and forming a symbiotic relationship with them. The resulting structure is called a mycorrhiza, or literally fungus-root. The fungus acquires carbohydrates from the host plant, but the host plant benefits in a wide variety of ways. First, water and nutrients absorbed by the fungal hyphae are transferred to the roots. Not only is the absorbing surface of the roots effectively increased, but the hyphae are able to absorb mineral elements that are in forms normally unavailable to roots. The elements proven to be absorbed more efficiently by mycorrhizae than roots are phosphorous, potassium, calcium, copper, and iron.

Roots of some mycorrhizal associations have been found to be resistant to infection by root rotting fungi and parasitic nematodes. The source of resistance has not been fully defined yet, but is probably a combination of things. The mycorrhizal fungus may present a physical barrier to the pathogenic fungus and/or produce antibiotics that limit growth of the pathogen. It is also possible that the mycorrhizal fungus stimulates the host to produce chemicals that inhibit the growth of any other fungus on the root. Once a root is infected by one mycorrhizal fungus it is even difficult to infect that root system with a different mycorrhizal fungus.

Plants with mycorrhizal roots may survive and grow better than non-mycorrhizal plants under adverse conditions

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[1]Metro. Tree Impr. Alliance (METRIA) Proc. 3:77-82, 1980.

such as high soil temperature, pH extremes, and soils with a high metal content. How the mycorrhizae accomplish this is not well understood, but it appears to be related to an ability of the fungus hyphae to selectively absorb essential mineral elements under the adverse conditions.

To achieve these benefits, we must thoroughly understand the different types of mycorrhizal associations and the implications of their differences. There are ectomycorrhizae, endomycorrhizae, and ectendomycorrhizae. The hyphae of ectomycorrhizal fungi grow in the intercellular spaces of the root; they do not penetrate the cells. They also form a dense fungal mantle around the root tips and extend out into the soil. Most ectomycorrhizal fungi are basidiomycetes and reproduce by forming basidiocarps, which are nothing more than puffballs. The airborne spores are easily dispersed over a large area. Examples of genera of trees forming ectomycorrhizal associations are listed in Table 1.

Table 1. Plant genera forming ectomycorrhizal associations

Abies	Fagus	Populus
Alnus	Larix	Pseudotsuga
Betula	Ostrya	Quercus
Carpinus	Picea	Salix
Cedrus	Pinus	Tsuga
Corylus		

The hyphae of endomycorrhizal fungi penetrate the root cortical cells and extend out into the soil, but do not form a fungal mantle around the root tips. Some form structures in the root cells called vesicles and arbuscules and are referred to as vesicular-arbuscular (VA) mycorrhizae. Most are phycomycetes and reproduce by forming chlamydospores in the soil near the surface of the roots. These spores must be disseminated by water or animals, as they rarely get windborne. This severely limits the spread of endomycorrhizae forming fungi into areas free of them. Despite this limitation, endomycorrhizae are naturally occurring in almost all soils and form associations with 90% of all higher plants. The genera of trees listed in Table 2 have been found to form endomycorrhizal associations.

Ectendomycorrhizae have characteristice of both, but will not be discussed here because they are consistently found on a very limited number of genera.

Table 2. Plant genera forming endomycorrhizal associations

Acer	Ginkgo	Robinia
Aesculus	Gleditsia	Sophora
Amelanchier	Liriodendron	Sorbus
Celtis	Malus	Ulmus
Cercidiphyllum	Platanus	Zelkova
Fraxinus		

Plants that form ectomycorrhizae do not normally form endomycorrhizae, and vice versa. However, the fungi within these broad categories are generally not host specific and will form mycorrhizal associations with a wide range of plants. For instance, the ectomycorrhizae-forming fungus Pisolithus tinctorius will form mycorrhizae with plants in most of the genera listed in Table 1.

The problem is that not all fungi impart the same benefits to their hosts, and a specific fungus may benefit one host more than another. Our goal is to determine which fungus-host combination will form the mycorrhizal association most beneficial to the plant. Plants growing on adverse sites develop the optimum relationship through the process of evolution. Those that have it survive and multiply, and those that do not eventually are crowded out and die. This process does not take a million years but may occur in the first year a seed or seedling is planted on a site such as an abandoned strip mine.

Where urban trees are concerned, though, we do not give them an opportunity to evolve. Trees are taken directly from nurseries, where they are grown in good soil and receive regular applications of fertilizer, and are often placed in environments not suitable for plant growth. The mycorrhizae on their roots are adapted to nursery conditions and not to the hostile environments found along city streets. The chance of a more beneficial fungus colonizing the roots is low because there may be no source of inoculum readily available; and even if there was, its infection of the roots would be inhibited by the existing mycorrhizal fungus.

To form the specific association most beneficial to the plants, they should be inoculated in the nursery during propagation. If they are not inoculated at the time of propagation, they will be infected by naturally occurring fungi, and it will be very difficult for the specific desired fungus to colonize them at a later stage in the production cycle.

Under standard nursery practices it would be relatively simple to inoculate the plants. Cuttings are rooted in sterile media and seedbeds are normally fumigated, a process which not only destroys root-rotting organisms but often kills mycorrhizae as well. Under these conditions the inoculum has no competition and can readily colonize the roots.

This brings us to the question of how exactly do we convert the potential benefits of mycorrhizae to actual benefits? First, we must determine which relationships produce the desired results--improved survival and growth of trees planted in urban environments. This problem can be approached in two ways. We can start with a specific tree and determine which fungus imparts to it the maximum benefit. The alternative is to start with a fungus which is known to be effective and determine which trees it will colonize and whether or not it will benefit all of them. The possibility exists that a fungus which forms a mycorrhizal association with two different tree species may benefit one but not the other.

The fungus which has received the most attention in this regard is *Pisolithus tinctorius*. Tree seedlings colonized with *P. tinctorius* have consistently shown increased survival and growth on adverse sites when compared with seedlings colonized by other mycorrhizal fungi. It is time to evaluate trees infected with this fungus on urban streets. The problem is that we need trees colonized as seedlings and grown for 7 to 10 years before they can be planted in the hostile urban environments.

After we have determined which fungus-host relationships are most beneficial, mycorrhizal plants will have to be planted and evaluated in a number of locations. There are strains of fungi which are effective in certain climates but not others. These limits will have to be defined for each fungus.

A system for propagating the fungus on a large scale must be developed. This is less of a problem for ectomycorrhizal fungi because they can be grown in pure culture. Abbott Laboratories is currently evaluating a system they have developed for producing inoculum of *P. tinctorius*. The system can be used to produce large quantities of other ectomycorrhizal fungi as well.

Producing inoculum of endomycorrhizal fungi on a large scale has a number of inherent problems. The fungi must be grown on roots of living plants for approximately three

months before the inoculum is ready to harvest. The chances of contaminating the roots with another mycorrhizal fungus are remote because spores of endomycorrhizae-forming fungi are not airborne, but spores of other fungi such as fusarium or botrytis may infect the host plants or their residue and contaminate the inoculum. These problems are currently being addressed by the personnel of Abbott Laboratories.

After systems for producing the inoculum on a commercial basis have been developed, the product must be evaluated. Initial comparisons between laboratory grade and commercially prepared inoculum of P. tinctorius suggested the laboratory grade was superior. This is to be expected with a new and rapidly developing technology. There is no reason to believe these problems will not be overcome, though.

Nurserymen must then be educated in the benefits of mycorrhizae and how to use them. Instruction on the storage and handling of inoculum, inoculation techniques, and special cultural requirements of mycorrhizae will have to be provided. Within a few years inoculation may be simplified to the point that tree seeds will be inoculated with a fungal symbiont in the same way that soybeans are now. The International Forest Seed Company is currently producing conifer seeds encapsulated with basidiospores of P. tinctorius for testing by researchers or interested nurserymen.

Mycorrhizae do not develop well under high fertility conditions. To educate nurserymen on how to encourage development of mycorrhizae on their plants, extensive field demonstrations will have to be carried out. Research is currently being performed on the use of slow release fertilizers during the time the mycorrhizal association is being established. In this way supplemental mineral elements are constantly being provided to the plant, but at rates low enough that they do not interfere with root colonization.

Finally, the consumers of these trees with customized root systems must be convinced of the trees' value. They will undoubtedly be more expensive, but a slight increase in cost should not be a deterrent. Replanting a tree that does not survive transplanting involves the costs of removal, purchasing a new tree, and planting it. When the proper mycorrhizal association has been found for urban environments, the amount of money saved in these steps will more than cover the increased cost of the customized trees. The added benefit provided at this point will be that the surviving trees will grow and develop better than trees currently being planted in urban areas.

The final point I want to make today is where trees with these customized root systems are needed. Sites for urban trees can be classified into four general categories: parks, wide tree lawns, narrow tree lawns, and holes in concrete. In parks, wide tree lawns, or any other open areas, tree roots will develop mycorrhizal associations with naturally occurring fungi. They will probably have access to adequate water and mineral elements. Customized trees may not be needed in these sites, and in fact, probably would not perform any better than trees grown under standard nursery practices.

Trees planted in the other site categories will have very restricted root zones and will be in soil not meant to support plant life. In these sites, carefully selected mycorrhizae can improve the survival and growth of urban trees by providing them with some or all of the recognized benefits of their associations.

DETECTION, DESCRIPTION AND TREATMENT OF GIRDLING ROOTS ON URBAN NORWAY MAPLE TREES[1]

by Robert L. Tate, Assistant Professor of Forestry, Cook College, Rutgers University, P.O. Box 231, New Brunswick, N.J. 08901

ABSTRACT.--Girdling roots are examined and described on street-side Norway maple trees (*Acer platanoides* L.) in Ann Arbor, Michigan. Treatments consisting of cutting girdling roots, fertilizing and pruning foliage were evaluated after two years and found to be of no benefit to girdled trees.

From August 1977 to August 1979 this study was made on 410 Norway maple trees (*Acer platanoides* L.) planted between 1925 and 1928 on the sidewalk extensions in the west-central section of the City of Ann Arbor, Michigan. The objectives of the study were to 1) evaluate the degree to which girdling roots affect Norway maples growing along streets in this area; 2) gain information on the characteristics of girdling roots, such as diameter, number per tree, depth, degree and severity of girdling and relative percentages of surface and subsurface occurrence; 3) identify and evaluate the effects of factors that contribute to the formation of girdling roots; 4) determine if treatments of fertilizing and trimming benefit girdled trees after two growing seasons; 5) determine if removal of girdling roots affect the health and vigor of trees; and 6) confirm the most effective measures for evaluating the effects of treatments.

GIRDLING ROOT CHARACTERISTICS

Thirty-five percent of the girdled trees were girdled by only one root, 46 percent were girdled by 2 to 3 roots and 19 percent were girdled by 4 to 9 roots. The mean diameter of all girdling roots was 2.5 inches (6.4 centimeters). Surface girdling roots have a significantly larger mean diameter than subsurface girdling roots (3.38 vs. 2.22 inches [8.59 vs. 5.64 centimeters]). On the average, 2.4 girdling roots were found on each girdled tree. Seventy-three percent of the girdling roots were subsurface. The mean depth of subsurface girdling roots was 2.5 inches (6.4 centimeters), and 79 percent of them were found within 3 inches (7.6 centimeters) of the ground surface. There was no grafting between girdling roots and trunks.

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[1]Metro. Tree Impr. Alliance (METRIA) Proc. 3:83-87, 1980.

FOLIAGE CHARACTERISTICS

Most of the trees, whether girdled or not, displayed dark-green leaves. The percentage of girdled trees with leaves that were lighter in color than normal was nearly twice that of non-girdled trees, but these differences were not significant. Smaller-than-normal leaves were more common on girdled than on normal trees. The differences in leaf sizes between normal and girdled trees were significant. Girdled trees had a considerably greater proportion of deadwood (foliage dieback) in their crowns than normal trees but the difference was not significant. In August 1977 girdled trees and normal trees did not differ significantly in vigor, crown diameter or total height.

BOLE CHARACTERISTICS

Bole characteristics such as the absence of normal trunk flare, a bulge near the ground line and the presence of a slightly flat or concave area of the trunk near the base were measured. Normal trunk flare was found on 66 percent of the non-girdled trees compared to 24 percent of the girdled trees. Twice as many girdled trees exhibited abnormal lower-bole characteristics as did non-girdled trees.

ENVIRONMENTAL CHARACTERISTICS

Extension width and distances between the bole and sidewalk and curb were measured. The proportions of normal and girdled trees were about the same in all extensions encountered regardless of whether the trees were planted in the center of the extension or off-center nearer curb or sidewalk.

Significantly more roots began to deflect along lines perpendicular to the curb or sidewalk than along lines in 6 other positions. Only 4 percent of the roots were deflected by physical contact with the concrete associated with curbs, sidewalks or driveways.

DEGREE OF ROOT GIRDLING

Most of the girdled trees did not appear to be severely girdled. Fifty-three percent had no more than one-quarter of the bole encircled by roots. Only 5 percent of the trees had roots that were overgrown by more than 0.6 of their diameters. Bole overgrowth was not great.

RESPONSE TO TREATMENTS

Measures of foliage characteristics such as leaf color, leaf size and general foliage dieback, tree-vigor rating, growth and tree mortality were taken during August 1979 to determine the benefit, after two

growing seasons, of combinations of treatments to trees with girdling roots.

There was no appreciable difference in the proportion of dark-green and medium-green leaves between girdled trees with roots cut and girdled trees with roots not cut. Fertilizing and pruning girdled trees whose roots had not been cut did not affect the proportion of dark-green and medium-green leaves compared to other individual treatments.

The proportion of smaller-than-normal leaves on girdled trees was not reduced by any combination of cutting girdling roots, fertilizing leaves, or removing live limbs.

The amount of foliage dieback after two years was less on girdled trees with roots cut compared to girdled trees with uncut roots but the difference was not significant. Individual treatments on girdled trees with roots cut did not reduce the amount of foliage dieback. Treatments did not affect the vigor of treated trees as compared to untreated trees.

The differences in amounts of annual twig growth which might be attributable to the treatments were small. In general, all study trees grew more in 1979 because the 1979 growing season was wetter than normal. Girdled trees with roots cut grew slightly more than non-girdled normal trees. During the two-year period of study, girdled trees with roots cut grew slightly more than non-girdled normal trees and girdled trees without cut roots.

Tree mortality was noted during August 1979. During the study, 7 girdled trees and none of the normal (non-girdled) trees died.

CONCLUSIONS

This study has shown that the magnitude of abnormal foliage characteristics and dieback is greater on girdled trees than on non-girdled trees. The degree of magnitude, though not significant, is large enough to be marginally attributable to the effects of root girdling. Measures of abnormal foliage characteristics and dieback are useful as diagnostic indicators only when girdling is so severe that irreversible damage to the tree has occurred. The predictive value of these characteristics is small and unreliable.

Even though it is not known how long the 50-year-old study trees have been girdled, their long-term growth does not appear to have been affected by girdling roots. Comparison of the total heights, crown diameters and diameters at breast height shows no significant difference in accumulated growth over the 50-year life span of girdled and non-girdled trees.

Other conclusions are as follows: Ratings of tree vigor are of no predictive value in determining whether trees are girdled by subsurface roots. Abnormal trunk-types are extremely valuable and highly significant as a diagnostic tool to predict the presence of subsurface girdling roots. Narrow extension widths do not appear to influence root girdling. The percentage of girdled trees as compared to non-girdled trees did not increase as the widths of extensions decreased. Most of the girdled trees are girdled by more than one small, shallow subsurface girdling root and are not girdled deeply. Because most of the girdling roots are found below the soil surface, the cost of excavating and treating is large.

There is no clear indication that treatments of fertilizing or pruning, or both, benefit girdled trees whether or not their roots are cut. No single measure or combination of measures was found that indicated a response to treatment. Removal of girdling roots did not affect the overall condition of girdled trees when other treatments were withheld. Root pruning, leaf fertilization and crown pruning did not appear to benefit girdled trees during the first two years following treatment. However, the short length of time between treatments and evaluation probably influenced the ability to judge the effectiveness of individual measures of treatment and overall tree response.

From the standpoint of cost and time spent on excavating and treating girdled trees, treatment of girdling roots is probably not appropriate on trees similar to those observed in this study. The dollars expended treating each tree probably should be invested in services such as tree planting, fertilization and insect and disease control.

MANAGEMENT IMPLICATIONS

The purpose of this section is to discuss the implications based on the results of this study with respect to management of urban street trees.

The chief problem in a study similar to this is the large number of unknown and uncontrolled variables that may influence results. For example, the environment in which street trees grow is highly complex and not properly understood. From city to city, planting practices vary and tree maintenance techniques are not uniform. From tree to tree there is a lack of visible uniform symptoms of stress. Moreover, the literature on the subject of girdling roots of street and landscape trees is sparse.

Only one tree species was examined in this study, so general conclusions about all girdled street and landscape trees cannot be made. Although the Norway maple is a popular and widely planted street-tree species, other species of trees need to be studied. Additionally, the time

period of two years used to evaluate treatments and their response needs to be extended several more years. I intend to conduct a follow-up study to further evaluate treatment over a longer period.

Even though there was no single reliable indicator of subsurface girdling roots except abnormal trunk-type, additional study needs to be initiated to identify other characteristics which may predict subsurface girdling roots.

This study suggests that there is little biological and aesthetic value in removing girdling roots and subsequently fertilizing and pruning the tree. Perhaps additional treatments not identified here, such as bole injection of trace elements, root-growth stimulants and inarching grafting techniques to bypass the root-girdle, should be examined to evaluate their worth in promoting overall tree vigor and longevity. Also, additional measures of treatment response should be identified and evaluated.

Extension width and soil texture did not appear to influence root girdling; few roots were deflected by physical contact with curbs, sidewalks and driveways. Nearly two-thirds of the girdled trees were girdled by more than one root; improper planting technique probably contributed to the abnormal growth of roots on these study trees. Urban foresters should make certain, through training and supervision, that tree planting is done properly.

Since girdling roots do not appear to have affected the long-term growth of the study trees, treatment is probably unnecessary in light of its high cost ($43.00 average cost per tree) if a reasonable life expectancy of Norway maple street trees does not extend much beyond 50-60 years.

Because most urban foresters purchase a large amount of bare-rooted trees for street planting from commercial nurseries, efforts should be made to make certain that potential girdling roots are removed at the nursery prior to delivery.

Since this study dealt with older trees, future studies should examine younger trees of various ages to determine if and when symptoms begin to occur and if treatment is beneficial.

CHARACTERIZATION OF STREETSIDE SOILS IN SYRACUSE, NEW YORK[1/2]

by Phillip J. Craul, professor of soil science, and
Charles J. Klein, research assistant
SUNY - College of Environmental Science and Forestry
Syracuse, New York 13210

ABSTRACT.--Streetside soils are shown to have bulk density, pH, specific conductance, and weight loss on ignition somewhat higher than native soils, and lower air-filled pore space and available water. Aeration status of the soil is shown to be a potential major problem, whereas street salting has a small effect on calculated osmotic potential.

THE PROBLEM

In 1961, John Van Camp (1961) gave a paper at the 37th National Shade Tree Conference professing the importance of a healthy root system to the vigor of a tree, and discussed the relationship between a tree and the root environment. He concludes his paper with "much basic research work and many intelligent observations are needed if we are going to keep pace with the tree problems that lie ahead." The problems that lie ahead are here and yet we have accomplished little basic research on the soil environment.

One omission is basic data on streetside soil physical and chemical properties. Since these soils are disturbed or manipulated, they do not always have the expected properties of native or natural, undisturbed soils. A confounding factor is the complex root environment found below

1/ Funded through cooperative aid grant 23-002 from U.S. Forest Service, Urban Forestry Project, Syracuse, N.Y.

2/ Metro. Tree Impr. Alliance (METRIA) Proc. 3:88-101, 1980.

a planted tree (Figure 1). Three soil materials are present through which the tree roots must elongate: (1) the tree ball; (2) the backfill soil; (3) the soil material in which the tree pit has been prepared. Tree roots should penetrate the surrounding soil material (3) in two to three growing seasons (Lyford and Wilson, 1966). It is this material which interests us as soil scientists concerned with the longevity of the urban tree rather than planting survival. The latter is a separate question and is left to another study.

THE STUDY

To develop basic information on streetside soil physical and chemical properties, 128 tree planting sites within the city of Syracuse, N.Y. were observed for profile characteristics, and soil samples obtained for laboratory analysis of bulk density, pH, weight loss on ignition, specific conductance, chloride content and available water (Black, 1965). These sites were sampled through a tree replanting program of the Syracuse Department of Parks and Recreation, and therefore were non-uniformily distributed over the five geomorphic surfaces comprising the city landscape: upland till plains thick to bedrock, upland till plains thin to underlying bedrock, alluvium and gravel floodplains, glacial outwash, and urban made land (Figure 2). The soils are comprised of shallow to deep calcereous glacial till soils in various drainage sequences, with and without a fragipan, moderately deep alluvium and deep gravelly well-drained outwash soils, and urban made land, consisting of hard and soft fill over somewhat poorly drained to poorly drained soils, created as the city developed from its first settlement. The modifications of the soils are related to the landform and the chronological age of the development. Physiographic modifications were made only where necessary in the early urbanization of the city. The flat valley areas (alluvium and glacial outwash) required little modification. Hillslopes required more cut and fill and are more highly modified, but the basic topographic shape was maintained. More recent urbanization into these areas result in greater modification of the surface and hence, the soil profile due to the availability of heavier machinery. Fill is highly modified regardless of where it occurs. The less densely urbanized suburbs exhibit topographic features and soil profiles nearly similar to those of the natural landscape.

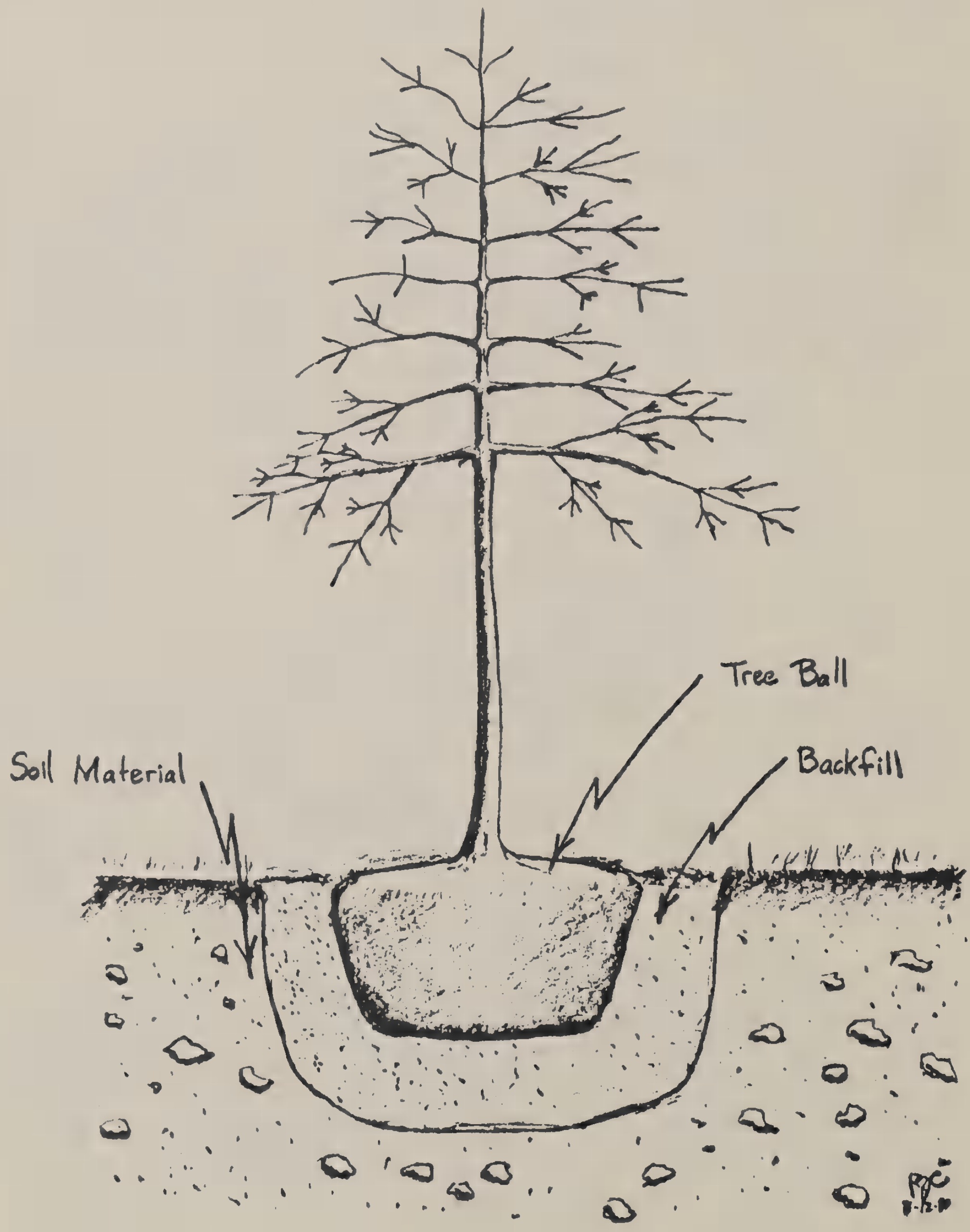

Figure 1. The planted tree showing the ball, backfill, and surrounding soil material.

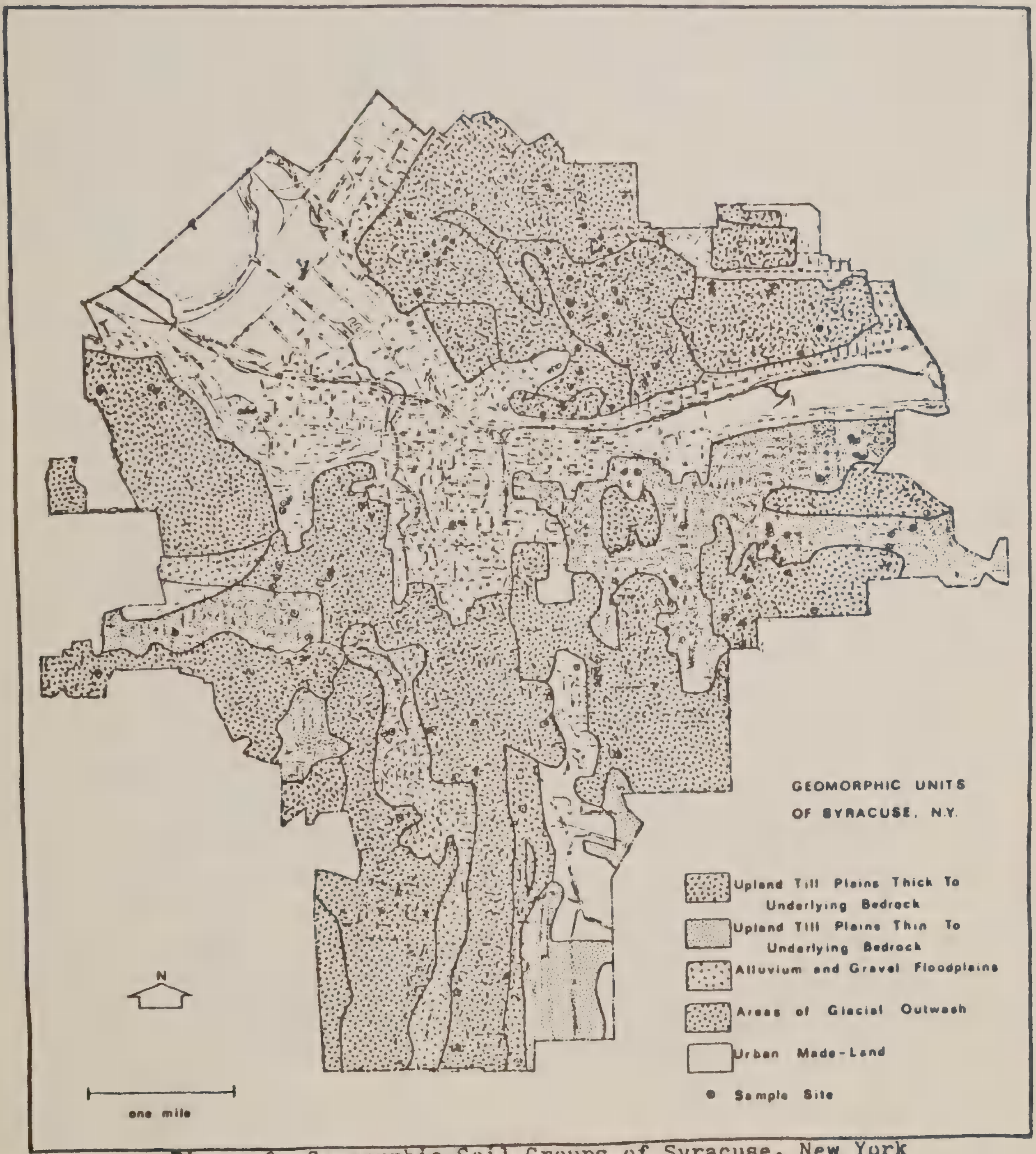

Figure 2. Geomorphic Soil Groups of Syracuse, New York
(from Soil Association Map, aerial photographs in
Onondaga County Soil Survey Report)

STREETSIDE SOIL PROPERTIES

Profile Modification

Profile modification is defined as that condition in the soil profile where: (1) some portion of the upper profile consists of material placed as fill over a natural soil or a portion thereof hence a lithologic discontinuity; or (2) the upper portion is stripped away and later replaced with the same material; or (3) the entire soil profile may consist of fill. The modification may be comprised of changes in properties such as bulk density, structure, possibly texture and organic matter, as well as the chemical properties of pH and nutrients. These changes are partially caused by intermixing or incorporation of non-soil material commonly associated with development construction such as fragments of brick, coal, wood, metal, ashes, etc. The extent and degree of modification has varying levels of influence on tree root growth as correlated with its effect on the ease of root penetration, available water, air-filled pore space and possibly, nutrient status.

The observed streetside soil profiles of Syracuse appear to fall into five modified profile classes: (1) 6 cm to natural profile or least modified of the sampled soils, and include mostly the glacial outwash and alluvial soils; (2) 11 cm to natural profile of glacial outwash soils; (3) 35 cm to natural profile mainly on thin glacial till soils; (4) 55 cm to natural profile on thick and thin glacial till soils and upland outwash; (5) 65 cm or more in fill to a natural profile or watertable comprising most of the urban made land of Figure 2. However, several of these classes may be represented within a landscape, and the average profile values for layer depths have the effect of masking any clear relationships between depth of modification and average values of soil physical properties different from what would be expected in the natural profile. The evidence for modification was primarily on the basis of the presence of incorporated non-soil material in the profile, some changes in color and the appearance of a structural discontinuity between layers. Additional analysis of individual profile data is required to develop a clearer relationship between modification and significant differences in bulk density, available water and air-filled pore space.

Soil pH

Relatively high pH values (Table 1) are expected since most of the soil parent material in the Syracuse area is influenced by outcropping and intermixing of material from various limestone strata. Comparison with the pH values of natural soils in Table 2 indicate that the pH values for the streetside soils are at the upper limit of the ranges for natural soils. The values are further inflated due to the use of calcium chloride as salting material on streets in the winter, and subsequent leaching has moved the calcium into the subsoil. Free carbonates have been observed in several of the profiles.

Specific Conductance

The specific conductance values are quite variable between soil groups as well as within the profiles. The large values observed in the recent alluvium soils (Group IV, Table 1) may be due to accumulation through concentration of drainage water in this portion of the landscape. Values over 1.0 mmho/cm are necessary before most plants are affected (Wilde et al., 1972). Further, calculations using the formula:

$$\text{osmotic pressure, bars} = 0.36 \times \text{EC, mmho/cm}$$

yields values that range from .22 to .94 bars with no established pattern among soils or within profiles. The contribution of osmotic potential to the soil solution was not sufficient to have a significant effect on increasing the moisture content of wilting point. Examination of the soil moisture in Table 3 leads us to believe that the osmotic potential would need to be several bars before significant effects are observed in these soils, since there are other more significant problems for root growth. However, specific conductance should not be ignored where soluble salts may be a contributory cause to adverse root environment.

Loss on Ignition

Weight loss on ignition of the profiles in Table 1 show the usual surface to subsoil trends found in natural soils. The values themselves are somewhat suspect in that the ignition procedure volatilizes carbonates as carbon dioxide when present in high amounts. This is probably the case in these soils, as subsequent chemical analysis shows high calcium

Table 1. Average soil property values for Syracuse streetside soil groups.

Soil Group	Number of Profiles	Layer Depth cm	Soil Reaction pH and Range	Specific Conductance mmho ± S	Loss On Ignition % ± S	Bulk Density g/cc ± S
I Glacial Till Uplands	53	0-16	7.7 (6.6-8.6)	.95 ± .26	7.2 ± 2.07	1.56 ± .07
		16-54	8.0 (7.1-9.1)	.62 ± .22	3.2 ± 1.10	1.82 ± .09
		54-65+	7.9 (7.3-8.8)	.61 ± .19	2.4 ± 1.15	1.85 ± .17
II Glacial Till Uplands Thin to Bedrock	18	0-10	7.9 (7.6-8.5)	.82 ± .29	7.1 ± 1.17	1.59 ± .07
		10-35	8.2 (7.4-8.6)	.57 ± .23	3.0 ± 0.63	1.84 ± .09
		35-65+	8.1 (7.5-8.6)	.64 ± .27	2.7 ± 0.53	1.81 ± .06
III Glacial Outwash	34	0-12	7.8 (7.1-9.0)	.78 ± .33	6.6 ± 1.38	1.62 ± .08
		12-38	8.0 (7.3-8.8)	.58 ± .14	3.3 ± 0.83	1.83 ± .17
		38-65+	8.0 (7.3-8.7)	.62 ± .52	3.0 ± 0.90	1.90 ± .06
IV Recent Alluvium	2	0-12	7.8 (7.3-8.6)	1.82 ± .28	6.3 ± 0.03	1.54 ± .01
		12-38	7.9 (7.6-8.2)	1.19 ± .18	4.0 ± 0.32	1.71 ± .03
		38-65+	8.2 (8.1-8.2)	2.60 ± .14	3.3 ± 1.35	1.60 ± .01
V Made Land	21	0-10	7.7 (7.3-8.5)	.89 ± .69	6.7 ± 1.65	1.73 ± .09
		10-35	8.0 (5.7-8.9)	1.45 ± .48	4.2 ± 1.30	1.82 ± .14
		35-65+	8.1 (7.7-8.6)	.66 ± .31	3.0 ± 1.57	1.79 ± .15

Table 2. Average soil characteristics for selected natural soils of Central New York.[a]

Soil Group	Depth cm	Soil Reaction Range, pH	Bulk Density and Range, g/cc	Available Water and Range cm^3/cm^3
I	0-30	5.6-7.3	1.39 (1.27-1.51)	.18 (.13-.20)
	30-83	5.6-7.8	1.59 (1.39-1.70)	.14 (.11-.18)
	83-152+	7.4-8.4	1.89 (1.73-2.00)	.08 (.06-.10)
II	0-41	5.6-7.3	1.14 (---)[b]	.15 (.14-.16)
	41-56	5.6-7.3	1.25 (---) ?	.16 (.13-.19)
	56-96	6.6-8.4	1.19 (---) ?	.16 (.13-.19)
	96-152+	---	---	---
III	0-23	5.1-7.3	1.40 (---)	.14 (.11-.17)
	23-48	5.6-7.8	1.70 (---)	.09 (.07-.11)
	48-79	6.1-7.8	1.60 (---)	.03 (.01-.04)
	79-152+	7.9-8.4	---	.03 (.01-.04)
IV	0-23	6.1-7.3	1.36 (---)	.20 (.19-.21)
	23-104	6.1-7.8	1.39 (---)	.18 (.16-.20)
	104-152+	---	1.38 (---)	---

a/ Data obtained from:
Hutton, F.Z., Jr. and C.E. Rice. 1977. Soil Survey of Onondaga Co., New York. U.S. Dept. of Agric. Soil Conserv. Serv. Supt. of Documents, Wash.
Cline, M.G. 1960. Physical and chemical characteristics of New York soils. Dept. of Agron. Mimeo Series No. 60-3 Cornell Univ., Ithaca.

b/ Ranges not available.

Table 3. Average moisture retention and pore space data for Syracuse streetside soil groups.

Soil Group	Depth	Bulk Density	Total Pore Space	Soil water tension, bars 0.1	1	3	5	15	Available Water	Macro-pore Space
	cm	g/cc	cm^3/cm^3			cm^3/cm^3			cm^3/cm^3	cm^3/cm^3
I										
Thick Glacial	0-16	1.56	.42	.27	.24	.21	.17	.14	.13	.15
Till Uplands	16-54	1.81	.32	.25	.24	.21	.19	.16	.09	.07
II										
Thin Glacial	0-10	1.59	.40	.32	.28	.24	.21	.18	.14	.08
Till Uplands	10-35	1.84	.31	.26	.16	.14	.12	.11	.15	.05
III										
Glacial	0-12	1.61	.40	.29	.23	.18	.16	.13	.17	.11
Outwash	12-38	1.87	.29	.27	.22	.19	.17	.14	.14	.02
IV										
Alluvium	0-12	1.54	-	-	-	-	-	-	-	-
	12-38	1.71	.36	.34	.31	.30	.26	.22	.11	.02
V										
Made Land	0-10	1.73	.35	.26	.23	.21	.18	.10	.10	.09
	10-35	1.81	.32	.27	.24	.18	.12	.09	.18	.05

content. Rough estimates indicate that the surface values are one to two percent too high, and that subsoil values are about one-half to one percent too high. Considering this adjustment, the values are still one to two percent greater than those found in natural soils of central New York (Arnold, 1968). This observation confirms that of Patterson (1976) in urban soils of Washington, D.C.

<u>Bulk Density</u>

The bulk density values for streetside soils given in Table 1 are greater than those of natural soil profiles (Table 2), confirming observations made by others that urban soils may exhibit some degree of compaction for various reasons. The soil textures of central New York natural soils center on loan, silt loam, clay loam or very fine sandy loam all of which are susceptible to compaction. The bulk density values for the streetside soils are about the upper limit of the range of natural soil bulk density values (Group I, Table 2). It is possible that like values would be observed in pastures on similar soils.

The surface bulk density values of the five soil groups, except madelands, indicate that root penetration would be moderately inhibited. The 1.73 g/cc average value for urban madeland indicates that root penetration would occur with some difficulty. It is reported that bulk density of 1.68 g/cc may seriously inhibit root penetration (Patterson, 1976), unless previously formed channels are present. Although the subsoil bulk density values exceed 1.68 g/cc, roots were observed in structural fractures, or in old root or fauna channels. Most roots were observed in the surface 35 to 40 cm portion of the profiles.

Vibration by frequent heavy vehicle traffic may be a contributing factor to the high bulk density values of these soils. Ground vibration was observed on numerous occasions during field sampling. When this event occurs while the soil is saturated, or nearly so, partial disruption of aggregates and repacking of the primary soil particles could take place, increasing the bulk density. However, we have no direct measurement of this effect. Compaction by foot traffic would be confined to the surface layers and is probably minimal except for sites in the central business district.

Macropore Space and Aeration

Macropores are the largest pores in the soil material and are defined as those pores having a diameter greater than 0.03 mm, and are air-filled within 48 hours after a saturated soil has been allowed to drain. As bulk density increases, or upon compaction, total porespace is reduced usually at the expense of macropore space. In some situations, disturbance to a soil may not reduce total pore space, but reduce macropore space causing a shift in the proportion of macropores to micropores. Most of the water stored in the soil occurs in the micropores. Gaseous diffusion is unable to occur in water-filled pores for all practical purposes, and so the macropores are those in which diffusion of oxygen into the soil and carbon dioxide out of the soil and into the atmosphere occurs.

Table 3 shows surface soil average macropore space ranged from .09 to .15 cm^3/cm^3 and that of subsoil ranged from .02 to .07 cm^3/cm^3. If .20 cm^3/cm^3 air space is required for adequate gaseous exchange between the soil and atmosphere (Bakker, 1970; Kramer, 1950), many of these streetside soils will exhibit restricted aeration even at field capacity. The problem is most acute in the subsoil.

Restricted aeration caused by soil compaction also implies an influence on the composition of the soil atmosphere. Reduced gaseous diffusion increases the carbon dioxide concentration and decreases the oxygen concentration. Carbon dioxide increases due to its production by root and microorganism respiration while oxygen is decreased by organism utilization and from the lack of resupply through diffusion from the atmosphere. Root elongation is inhibited at low oxygen and high carbon dioxide concentrations (Hopkins and Patrick, 1969), which would be expected in these subsoils. Tackett and Pearson (1964) studying cotton roots found the critical bulk density for adequate gaseous diffusion to be about 1.60 g/cc. Bulk densities greater than this value had little effect on further changes in oxygen or carbon dioxide concentrations, and therefore, impedence to root elongation became the primary factor.

Available Water

Available water is that water held in the soil against the force of gravity, but not so tightly that tree roots

cannot absorb it. Available water is held in the soil with a force that ranges from 0.1 to about 15 bars. The water held with less force within this range is more available to the root. Hence, water held at .08 bars is more available to the root than that held at 5 bars.

The surface soil available water averages from .10 to .17 cm^3/cm^3 and subsoil average values range from .09 to .18 cm^3/cm^3 (Table 3). It should be noted from comparing data in Table 2 that the streetside soils have available water values that are not significantly different from those of the natural soils. This confirms the earlier statement that the proportion of micropores or water filled pores is greater in the streetside soils with the greater bulk density values, since it would be expected that soils with greater bulk density would have less available water. The ideal medium-textured soil with a bulk density of 1.33 g/cm^3 would have a total pore space of .50 cm^3/cm^3 of which .25 cm^3/cm^3 is air-filled porespace (macropores) and about .20 cm^3/cm^3 as available water. The remaining .05 cm^3/cm^3 consists of micropores, but water contained therein is held with a force exceeding that exerted by tree roots. Thus, the available water of the streetside soils is less than that of the ideal medium-textured soil.

CONCLUSIONS

It is apparent streetside soil properties provide root-growing conditions that are characterized by low air filled porespace and available water, causing periods of restricted aeration or periods of limited water availability at different times during the year. The situation may be succinctly stated as being too much water in the dormant season and early spring and too little water in late summer and early fall for optimum growth of roots. The proportion of the profile exhibiting these conditions very much depends, on many sites, upon the depth of disturbance or modification of the soil profile caused by urban development.

Tree species adapted to the extreme stresses must be planted on these soils, or the soil properties modified in some way to provide more favorable growing conditions for tree species not adapted to the present ones.

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SELECTING TREES FOR CLAY SOILS[1]

by George H. Ware, Dendrologist,
The Morton Arboretum, Lisle, Illinois 60532

ABSTRACT.--The selecting of trees for urban planting in the Chicago region requires careful attention to the limitations of the widely prevalent clay soils. Springtime wetness may be partially alleviated by re-shaping the configurations of the landscape planting sites to improve drainage. Selection and improvement of urban trees tolerant of poor soil aeration continues to be of great importance in coping with clay. Ecological and environmental considerations are important in the search for better trees for metropolitan use.

The experiences and examples in this discussion are based primarily upon observations in the Chicago region. The cold winters and generally changeable weather present one set of adversities for urban trees and the widespread prevalence of clay soils presents another; the two are interrelated in their constraints on tree growth. The term "soil" is used primarily to refer to the medium in which tree roots are accommodated in urban areas, because the natural weathered mantle (or vertical sequence of horizons) is usually not intact in urban situations.

The Chicago region has extensive areas of soils derived from glacial till. These soils are often high in clay content, with very dense clay found at depths of two to three feet. Coping with these soils provides tree planting experience that is probably widely applicable to urban clay soils. Problems are intensified by soil disturbance accompanying large-scale construction projects, wherein surface and deeper materials are mixed. Most development involves extensive re-shaping of the land, producing a clay-rich and inhospitable medium for tree planting.

Springtime wetness is a major stress-maker for trees planted in clay material. Poor aeration is associated with failure of rootlets to develop or even the deterioration of rootlets, leading to transpiration stress in mid-summer because of impaired water uptake capacity. Also, proper nutrient uptake may be affected. Planting a tree in clay is essentially the same as planting one in a large container without a drain-hole.

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[1]Metro. Tree Impr. Alliance (METRIA) Proc. 3:102-106, 1980.

In Illinois, farmers cope with soil wetness by installing vast underground tile systems that collect water and pour it into drainage ditches or streams. Such tile lines make it possible for spring planting to be done weeks earlier than would be possible without such artificial drainage. Even with tile systems, there are certain fields that remain unplantable for weeks during years of heavy spring rainfall. Flatness of the landscape contributes to the sluggishness of drainage in farm fields. The same poor drainage is often present in lawns, gardens, parkways, and other areas into which flat farmland has been transformed. Indeed, there is too little awareness and insufficient regard for the effectiveness of drainage provided by the tile systems when land is being considered for urban development.

Coping with clay is a demanding challenge for tree planters, and experience seems to be the best way of gaining respect for the adversities presented by clay soils. Losses of planted trees in clay soils are often quite great, and the most skillful landscape architects and contractors resort to facilitating drainage by creating undulating land surfaces or low berms. Berms and gentle swales are commonly seen around buildings in condominium and apartment complexes and in industrial parks. Sometimes the balled trees and shrubs are set in place on level ground and low berms built up around them. Because berms are usually constructed of excavated material high in clay, good drainage is not necessarily insured. All too often berms are compacted during their construction. The slopes of the berm facilitate drainage, but lateral gravel seepholes hidden under the sod may also be needed to attain sufficient drainage.

Homeowners may not have sufficient space for molding their yard surfaces significantly. Still there are possibilities of selecting suitable planting sites around homes or preparing sites more skillfully. Some guidelines might be: Plant on slopes rather than on flat areas where water may stand; plant on a gentle mound, making sure that settling will not create a depression around the tree; prepare a hole with an extensive width to promote proliferation of roots in the top six inches where aeration is most favorable; and use mulches for moderating moisture and temperature levels of the mulched area and for reducing grass competition. Areas with soil profiles intact should be preserved if at all possible,to utilize a more favorable planting medium.

Alkalinity of urban soils is a widespread problem, especially in clay. Re-shaping of land surfaces not only may increase the amount of clay at the surface but also may raise pH levels because of the calcareous nature of deeper materials. Years of lawn watering with hard water or use of granular lawn fertilizer may raise pH levels. Run-off from concrete surfaces (patios, drives, walks, streets, etc.) may also increase pH.

Regions with clay soils are mostly localized but rather numerous in the United States. The Nashville Basin in Tennessee is underlain by limestone that weathers into shallow clay soils. Calciphilic plants are common. For example, red cedar (Juniperus virginiana L.)

glades are quite conspicuous. The blacklands of Texas and Alabama are geologically related and are comprised of clay soils with numerous characteristic tree and shrub species. Cedar elm (Ulmus crassifolia Nutt.) is a common tree along streets of towns in the Texas blackland regions. Still another region with calcareous soils is the Bluegrass Country of Kentucky.

Urban soils are often created by filling of low places or landscape re-shaping, utilizing raw geological material or dredged material. Much of the urban surface material of New Orleans is either deltaic clay or dredged clay. Spring wetness and alkalinity present problems similar to those of the Chicago region. The mixed materials underlying many urban areas become compacted, charged with lime and salt, and subject to excessive moisture because of drainage impediments.

Consideration of ways of lessening the limitations of a clay substratum is important, but the best prepared clay planting medium will accommodate successfully only certain species of trees. A useful rationale is that those trees successfully tolerating clay have certain physiological attributes in common. For example, floodplain and swamp species are generally successful urban trees. Not only do these species tolerate spring wetness but they also tolerate summer dryness, actually possessing a broad amplitude of endurance of adversity. American elm (U. americana L.), green ash (Fraxinus pennsylvanica var. subintegerrima (Vahl) Fern.), and silver maple (Acer saccharinum L.) are the main components of the floodplain forests of many of the rivers of eastern United States. All are successful urban street trees. Indeed, the widespread planting of American elm set the stage for Dutch elm disease devastation. Less common floodplain species are river birch (Betula nigra L.), swamp white oak (Quercus bicolor Willd.), and hackberry (Celtis occidentalis L.). These three are also desirable urban trees. Of course, cottonwood (Populus deltoides Marsh.) and black willow (Salix nigra Marsh.) are both floodplain species and are sometimes seen as urban trees.

Pin oak (Q. palustris Muenchh.) is a native of poorly drained flat areas that have acidic soils. Pin oak thrives in well-drained soils but often develops chlorosis in alkaline urban soils. Because acidification of such soils is often difficult, selection of oak species with more suitable ecological attributes seems to be a better direction. Requirements for such an urban oak should include the tolerance of both clay and alkalinity. Both Shumard oak (Q. shumardii Buckl.) and its close relative Texas red oak (Q. texana Buckl.) get along well on alkaline clay soils. Chinquapin oak (Q. muehlenbergii Engel.) is another oak at home on alkaline clay soils. Northern red oak (Q. rubra L.) does moderately well on slightly alkaline soils if drainage is adequate. Bur oak (Q. macrocarpa Michx.) is an excellent oak for heavy soils but its large size and broad crown may make it less appropriate than other oaks as a street tree.

Recommended tree lists exist for many of the towns and villages of the Chicago region. These lists are usually quite short and show considerable similarity. Green ash, honey locust (Gleditsia triacanthos L.), Norway maple (A. platanoides L.), sugar maple (A. saccharum Marsh.), red maple (A. rubrum L.), and hackberry are on most of the lists. 'Greenspire' and 'Redmond' lindens are on some of the lists, as is red oak.

Generally excluded are silver maple, pin oak, and Siberian elm (U. pumila L.). Still, in new neighborhoods the numbers of these three are quite great, mainly because homeowners insist upon quickly produced shade. However, recent large-scale contract plantings seem to emphasize green ash, honey locust, Norway maple, and red maple. Experienced landscape contractors in the Chicago region consider red maple and pin oak appropriate for those sites where the soil profile has been preserved intact, insuring a neutral to slightly acid topsoil. Both red maple and pin oak are subject to chlorosis on re-molded landscapes because of the predominantly alkaline clay root environment.

Some of the little-use and little-known tree species with considerable stress-tolerance are: blue ash (F. quadrangulata Michx.), Hesse European ash (F. excelsior L. 'Hessei'), pumpkin ash (F. tomentosa Michx.), European black alder (Alnus glutinosa (L.) Gaertn.), lacebark elm (U. parvifolia Jacq.), Japanese elm (U. japonica (Rehd.) Sarg.), Amur maple (A. ginnala Maxim.), hedge maple (A. campestre L.), and black maple (A. nigrum Michx. f.). Some suitable conifers are: European larch (Larix decidua Mill.), baldcypress (Taxodium distichum (L.) Richard), and limber pine (Pinus flexilis James). Northern white cedar (Thuja occidentalis L.) is rather commonly used and is surely one of the most utilitarian conifers for screening or hedge use.

The hawthorn group contains numerous species at home on clay soils. Hawthorns are often associated with disturbed landscapes, especially overgrazed and compacted pastures. Many hawthorn species are susceptible to cedar-hawthorn rust and its conspicuous disfiguration of foliage. Washington hawthorn (Crataegus phaenopyrum (L. f.) Med.) is relatively free of problems and has become one of the most commonly planted multiple-stemmed trees in midwestern states. It is especially satisfactory in landscape plantings of shopping centers. Because hawthorns generally fare satisfactorily in clay soils, the group may be considered as a source for new forms. Use of thornless cockspur hawthorn (C. crus-galli L.) might overcome some of the homeowners' dislike for the thorny branches.

Some of the species that present recurrent problems when planted in clay soils, and the use of which is generally discouraged in the Chicago region, are: paper birch (B. papyrifera Marsh.), mountain ash (Sorbus aucuparia L.), Japanese maple (A. palmatum Thunb.), and flowering dogwood (Cornus florida L.). These species are climatically hardy in the Chicago region but are not at home on clay soils. Those successful specimens of these species occasionally encountered in this region are usually found on soils overlying gravel deposits.

Where does one look for suitable new trees for clay soils? There are perhaps dozens of potentially useful kinds in areas of Asia climatically similar to the eastern U.S. These might be species, subspecies, or ecotypes. The presence of scores of mountain ranges enhances this possibility because the same species may vary physiologically and ecologically from range to range. Moreover, a wide variety of habitats, exposures, and substrata is found in each range. Better knowledge of provenance of some of the species commonly planted (such as Norway maple and little-leaf linden) should be sought. Improved material for understocks is especially needed.

The floodplains and swamps of North America contain additional species which have not been sufficiently utilized. The lower Mississippi Valley is home to quite a number of species little used even though most tolerate soil wetness and clay quite well. Hardiness, of course, poses possible limitations for use in northern urban areas.

Upgrading some familiar but often lowly regarded species is also a desirable direction. Single-stem (excurrent) forms of silver maple, box elder (*A. negundo* L.), and Siberian elm might make acceptable street trees because of better endurance of wind and ice storms.

Thus in selecting trees for clay soils, the study of functional attributes of trees, especially root system physiology, leads one to the natural landscapes of the world where tree species are at home on substrata with adversities similar to those of clay soils. These soil-stress tolerant populations are reservoirs from which can come aesthetically pleasing selections already possessing good survival qualities.

SELECTION OF TREES AND PLANTING TECHNIQUES FOR FORMER REFUSE LANDFILLS[1]

by I. A. Leone, E. F. Gilman, M. F. Telson and F. B. Flower, professor, graduate students and extension specialist respectively, New Jersey Agricultural Experiment Station, Cook College, New Brunswick, New Jersey 08903

ABSTRACT.--Sanitary refuse landfill sites are unsuitable for purposes requiring the building of permanent structures due to the amount of settling likely to occur. For this reason they are generally given over to some open space or recreational usage requiring the planting of vegetation. Numerous stress conditions, including oxygen depletion, elevated temperature, soil compaction, moisture deficiency and the presence of toxic or growth inhibiting gaseous or metallic constituents have been known to confront plants attempting to grow in landfill cover soils. In order to identify woody species most adaptable to the conditions prevailing in such soils, a tree-screening program was conducted on a typical former landfill site. Trees planted at the Edgeboro Landfill 4 years previously, produced less shoot and stem growth and shallower root systems than those on an adjacent non-landfill control. Of nineteen species replicated ten times, black gum and Japanese black pine appeared to be most tolerant and green ash and hybrid poplar, most sensitive to the landfill conditions. Root systems of the former were more shallow than those of the latter. Smaller planting stock (1-2 ft. tall) appeared better suited for landfill planting than larger trees (10-12 ft. tall). Balled and burlapped trees made better growth on the landfill than bare-rooted material. Of five gas-barrier systems tested, a backfilled soil trench lined with plastic sheeting over a gravel base and vented with vertical PVC pipes and 3-ft soil mounds with or without a 1-ft clay base proved effective in preventing the penetration of landfill gas into the rhizosphere of the test species. Inoculation of the roots of Scots Pine seedlings with the ectomycorrhizal fungus *Pisolithus tinctorius* caused increased growth of the seedlings over uninoculated controls.

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[1]Metro. Tree Impr. Alliance (METRIA) Proc. 3:107-117, 1980.

SANITARY REFUSE LANDFILL sites present unique stress environments for vegetation. The anaerobic conditions underlying the soil cover may be likened to those produced in flooded soils, but without the presence of excess water.

Oxygen deficiency is one of the principal causes of poor growth or death of plants in landfill soils, as it is in water-logged terrain. Combined with O_2 depletion is the presence in the soil of a number of gaseous decomposition products (Table 1) primarily carbon dioxide (CO_2) and

Table 1. Landfill Gases

Methane	60%
Carbon Dioxide	85%
Carbon Monoxide	Tr.
Ethane	Tr.
Ammonia	Tr.
Hydrogen Sulfide	Tr.
Ethylene	Tr.
Propylene	Tr.
Hydrogen Cyanide	Tr.

methane (CH_4), either of which may accumulate to concentrations greater than 50% of the soil atmosphere at any given time (4). Methane has been considered relatively inert for plants (11,13) but CO_2 at high levels can be deleteterious to root systems per se, or indirectly by replacing O_2 or by lowering soil pH (3,6).

Problems with toxic soil gases are not confined to the soil immediately over the refuse layers. Such gases have been known to migrate laterally from a landfill for hundreds of feet into adjacent farmland with consequent damage to crops (10).

Another effect of poor soil aeration is the lowering of the redox potential to a point where toxic trace elements may be solubilized and made more readily available to plants (11,12).

Landfill cover soils, characteristically shallow in depth, and of poor nutrient quality, are generally lacking in moisture, having no water continuum through the refuse strata to replenish that lost from surface layers (Fig. 1). Increased soil temperatures, whether from refuse decomposition or combustion, can lower the existing moisture level, stressing plants even further. (2) Decreased soil moisture will also tend to depress the flow of essential plant elements from soils already deficient in nutrients (7).

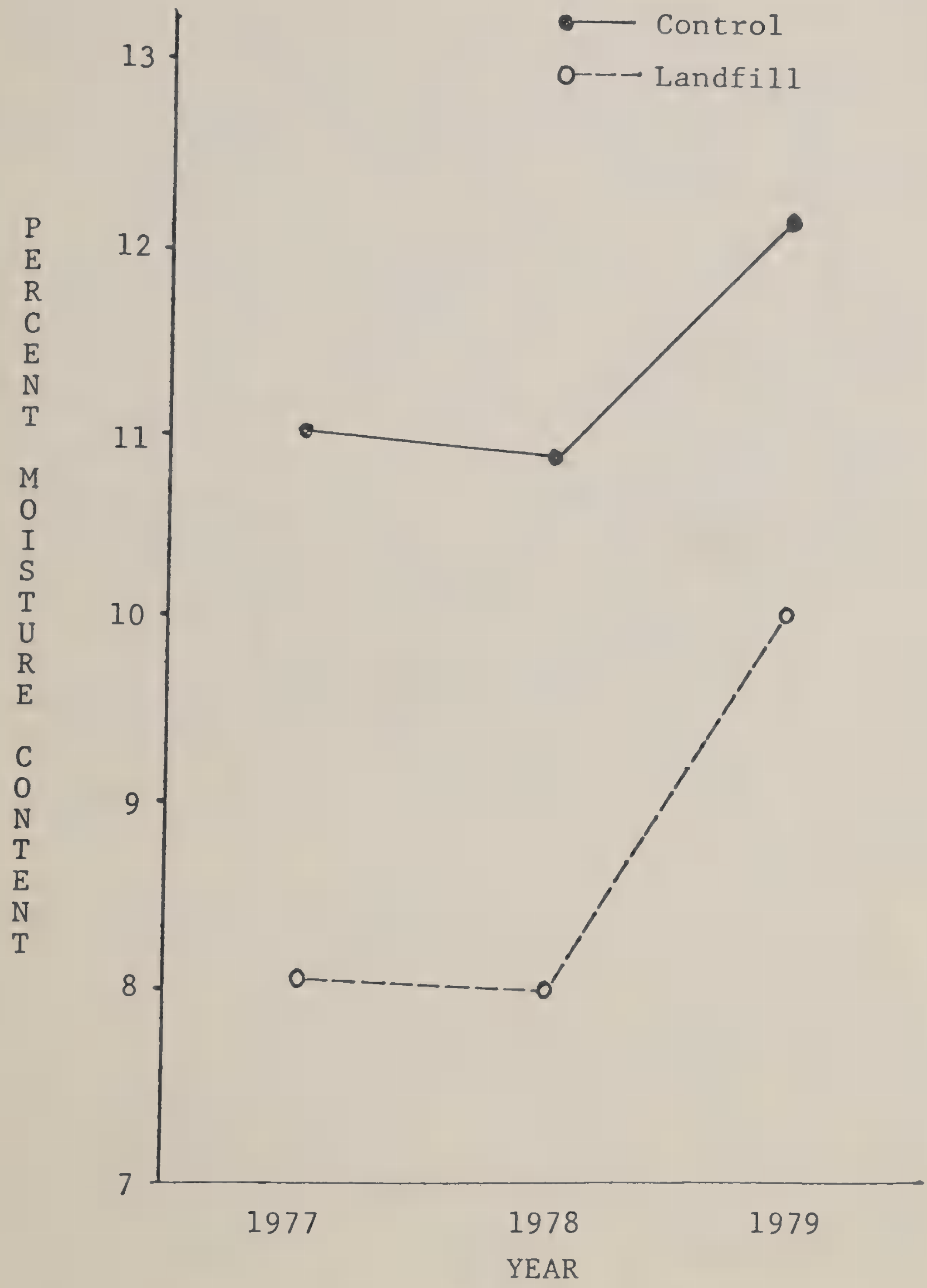

Fig. 1. Moisture content of landfill and control plots.

Soil compaction, initiated by the constant traffic of heavy motorized equipment and aggravated by continuous settlement, can further stress plants in landfill cover soils by decreasing total pore space and/or pore size (7).

In spite of all these drawbacks, the tendency, when such sites become available, is to attempt to grow vegetation, without considering the aforementioned factors. Whereas there has been some apparent success in establishing vegetation on former refuse landfills, as witness the South Coast Arboretum in Palos Verdes, California, which was built on a land-filled former diatomaceous earth mine (1), a site inspection of more than 60 other vegetated landfills throughout the United States has revealed otherwise (5).

In efforts to alleviate some of the stresses imposed by landfill conditions, our research group initiated a screening program to identify woody species capable of adapting to the adverse situations. Among the criteria for selection of species for the test were the following: (1) easily available (2) suitable for landscaping purposes, (3) tolerant of low O_2 environments and (4) tolerant of other urban stresses. On the basis of these criteria, nineteen species were selected, all of which are commonly used for landscaping purposes in this area (Table 2). Among these, eight were selected for tolerance to low O_2 levels (red maple, green ash, honey locust, bayberry, black gum, American sycamore, and weeping willow.) Particular hope was held for green ash which is reported to transport O_2 from shoots to roots and to be capable of oxidizing its rhizosphere in flooded soils (8,9). Red maple, American sycamore and honey locust are also cited for tolerance to water-logged soils (14). Three of the species (Ginkgo, sycamore, and black pine) are considered tolerant to other urban stresses (7). Two species (American basswood and Japanese yew) represented landfill-sensitive types for comparison (5).

These species were placed randomly, in replicates of ten, on the Edgeboro landfill located several miles from the Cook College campus in East Brunswick, NJ; and in a control plot of similar size which was cleared from a near-by woodlot and topped with the same type and depth of soil as that used to cover the landfill. The trees have been routinely fertilized, limed, irrigated, pruned, and generally maintained for four years. Although a majority of the trees have survived, all the weeping willows, rhododendrons and euonymus on the landfill died by the end of the 3rd year, apparently unable to withstand the periods of drought characteristic of such sites during the summer.

Table 2. Species Selected For Vegetation Growth Experiment At Edgeboro Landfill

Abbreviation	Latin Name	Common Name	Selection Criteria*
Ar	*Acer rubrum*	Red maple	1,2,3
Ea	*Euonymus alatus*	Winged-Euonymus	3
Fl	*Fraxinus lanceolata*	Green ash	1,3
G	*Ginkgo biloba*	Ginkgo	3,5
Gt	*Gleditsia triacanthos*	Honey locust	1,3
Ls	*Liquidambar stryaciflua*	Sweet gum	3
Mp	*Myrica pennsylvanica*	Bayberry	1,3
Ns	*Nyssa sylvatica*	Black gum	1,3
P	*Populus sp.*	Poplar (Hybrid)	3
Pe	*Picea excelsa*	Norway Spruce	3
Pm	*Populus sp. m.*	Poplar (Mixed Hybrid)	
Po	*Platanus ocidentalis*	American sycamore	1,3,5
Ps	*Pinus strobus*	White pine	3
Pt	*Pinus thunbergi*	Black pine	3,4
Qp	*Quercus palustris*	Pin oak	1,3
R	*Rhododendron Roseum elegans*	Rhododendron	3
Sb	*Salix babylonica*	Weeping willow	1,3
Ta	*Tilia americana*	American basswood	3,6
Tcc	*Taxus cuspidata capitata*	Japanese yew	3,6

*Selection Criteria

1. Tolerant of low O_2 environments.
2. Ubiquity.
3. Aesthetic landscaping purposes.
4. Sea salt tolerance.
5. Tolerant to city conditions.
6. Suceptibility to landfill gases.

On the basis of shoot length and stem area increase measured for each species on the landfill and control plots, the surviving trees were ranked in order of decreasing tolerance to the existing landfill conditions (Table 3). From these data it appears that black gum, Norway spruce, and Ginkgo were the most suited for the conditions on Edgeboro Landfill. Species tolerant to low O_2 environments (especially green ash and honey locust) were located very low on the tolerance list. Lack of sufficient moisture may have curtailed the growth of these water-loving species (7). Rapidly growing trees (hybrid poplar, honey locust, and red maple) appeared to be more sensitive to the landfill conditions than slow growers when compared to growth of controls. However, they also produced more absolute growth on the landfill than the more slow-growing trees; so if amount of growth is the criterion rather than relative growth, these species might be considered.

Acid-loving plants (Japanese black pine, Norway spruce, black gum, bayberry) were tolerant of the low soil pH (4.5) whereas green ash, red maple, American sycamore were adversely affected.

Root systems of the more tolerant species (Japanese black pine and Norway spruce) were much shallower, both on the landfill and control, than were less tolerant species. The ability to develop a shallow root system may be one of the over-riding factors in the adaptability of trees to landfill conditions. Those more able to move their root systems to a higher soil level may thus avoid contact with the toxic or growth-curtailing gases produced in a landfill.

Other factors which appeared to favor the chances for survival of landfill trees are smaller trees at planting over larger sizes of the same species, balled-and-burlapped roots over bare-rooted stock, extensive irrigation over poor irrigation, gas-barrier systems such as soil mounds or lined and vented back-filled trenches over unmodified landfill areas (7).

A useful guide for the evaluation of potential landfill gas problems is presented in Table 4. "On the spot" examination of soil characteristics such as odor, color, moisture, temperature and friability can aid in the detection of landfill areas likely to present problems for growing plants.

Table 5 summarizes some of the factors to be considered by anyone planning to establish vegetation on a completed landfill. Even before the selection of suitable species and maintenance procedures, attention to the proper

Table 3. Relative Tolerance of Species to Landfill Conditions

Rank a	Species	Σ "t" Statistics b
1	Black gum	2.66
2	Norway spruce	3.22
3	Ginkgo	4.95
4	Black pine	6.59
5	Bayberry	6.62
6	Mixed poplar	8.13
7	White pine	8.94
8	Pin oak	8.96
9	Japanese yew	8.98
10	American basswood	9.48
11	American sycamore	10.66
12	Red maple	10.95
13	Sweet gum	12.62
14	Euonymus	14.25
15	Green ash	14.87
16	Honey locust	15.05
17	Hybrid poplar	20.33
18	Weeping willow	21.20
19	Rhododendron	All plants died

a. Rank 1 = the best growth when experimental plot is compared to the control plot, i.e. most tolerant of landfill conditions.

b. Σ "t" = the sum of the "t" statistics for shoot length in 1976; leafweight, basal area increase, root biomass and shoot length in 1977 comparing the experimental area with the control.

TABLE 4. GUIDE FOR EVALUATION OF LANDFILL SOIL GAS PROBLEM

CHARACTERISTIC	ANAEROBIC SOIL	AEROBIC HEALTHY SOIL
ODOR	SEPTIC	PLEASANT
COLOR	DARKER	LIGHTER
MOISTURE CONTENT	HIGHER	LOWER
FRIABILITY	POOR	GOOD
TEMPERATURE	HIGHER	LOWER

Table 5. Control Techniques

1. Suitable Species-

   Shallow Rooted, Adapted to Anaerobic Conditions.

2. Cultural Methods-

   Adequate Lime, Fertilizer, Top Soil For Cover, Irrigation.

3. Soil Amendments-

   Shredded Refuse, Mulch, Sewage Sludge.

4. Landfill Construction-

   Proper Grading, Compaction, Adequate Depth and Quality of Top Soil.

5. Planting Techniques-

   Vented or Lined Trenches, Mounds.

6. Gas Collection.

construction of a landfill can do much to prevent or minimize many of the adverse conditions encountered by plants in completed landfills.

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RELATIONSHIP OF FOREST DESTRUCTION AND SOIL DISTURBANCE TO INCREASED FLOODING IN THE SUBURBAN NORTH CAROLINA PIEDMONT [1]

by Barrett L. Kays, Soil Scientist/Landscape Architect, Sunbelt Planning Associates, Inc., Raleigh, North Carolina

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ABSTRACT. A research study was conducted to determine the significance of soil disturbance, urban vegetation and infiltration in suburban stormwater management. A considerable amount of suburban land is commonly denuded and soil sufficiently disturbed to produce a marked increase in downstream flooding. Sensitive land use planning can significantly reduce the amount of tree destruction and soil disturbance during urban development. Reclamation of disturbed sites through urban soil and tree management has the potential to significantly increase the low infiltration conditions thereby reducing the volume of stormwater runoff.

Urban areas have always been plagued by drainage problems and flooding due to the impact of intense rainstorms, while forests and managed landscapes generally have sufficiently intact tree and soil conditions to avoid significant stormwater runoff problems (Dunne, et al 1975; Hewlett and Nutter 1970). Management of trees and soils in urban and suburban areas offers a means to minimize stormwater runoff, to maintain a base flow in streams and to improve water quality. Unnecessary destruction of trees and disturbance of soils during metropolitan development creates increased water management problems.

The hydrology of suburban watersheds is greatly dependent upon the amount and condition of vegetation and soils present after urbanization (Leopold 1968). It has been well recognized that water runoff increases with construction of buildings, roads, etc. in the watershed (Carter 1961; Putnam 1972). However, little thought has been given to actually reducing water management problems by carefully managing trees and soils during and after urbanization (Felton and Lull 1963; Kelling and Peterson 1975). The intent of this

[1] Metro. Tree Impr. Alliance (METRIA) Proc. 3:118-125, 1980.

paper is to illustrate some tree and soil management approaches that have been developed through a research study in the suburban Piedmont province of North Carolina (Kays 1979). Although the research study was primarily directed towards soil-water management, vegetation is the principle means of achieving this type of non-structural watershed strategy. The Sudbury Watershed in Charlotte, North Carolina will be used to illustrate this suburban water, tree and soil management approach.

We all know that trees and soils will aid in the retention of rainfall and thus will decrease and slow runoff to the stream. In order for the natural system to aid in urban stormwater engineering, the natural processes must work under most adverse climatic conditions; that is, short duration high intensity rainstorms that follow wet antecedent conditions. In other words, a sudden torrential rainstorm that occurs after at least one day of antecedent rain. How do we make the natural system work for these rare events . . . rain events that occur once every five to ten years in which severe flood damage may occur?

Historically the Sudbury Watershed (150 ha) in Charlotte, North Carolina had agricultural and forest land uses (Figure I). By 1968 (Figure II) the watershed had become completely urbanized. This study area was selected to measure infiltration and runoff. The dominant soil conditions on the watershed are given in Table I. These clayey subsoils are naturally quite infertile.

TABLE I

Dominant Upland Soil on Sudbury Watershed
Charlotte, NC

Soil Classification:	Typic Hapludult, Clayey, Kaolinitic, Thermic, Cecil Series
Subsoil Properties:	
Particle size -	Sand 20-30% Silt 15-20% Clay 50-60%
Base saturation -	12-16%
Cation exchange capacity, pH 7 -	7-8 meq/100 g
Clay mineralogy -	57-58% Kaolinite

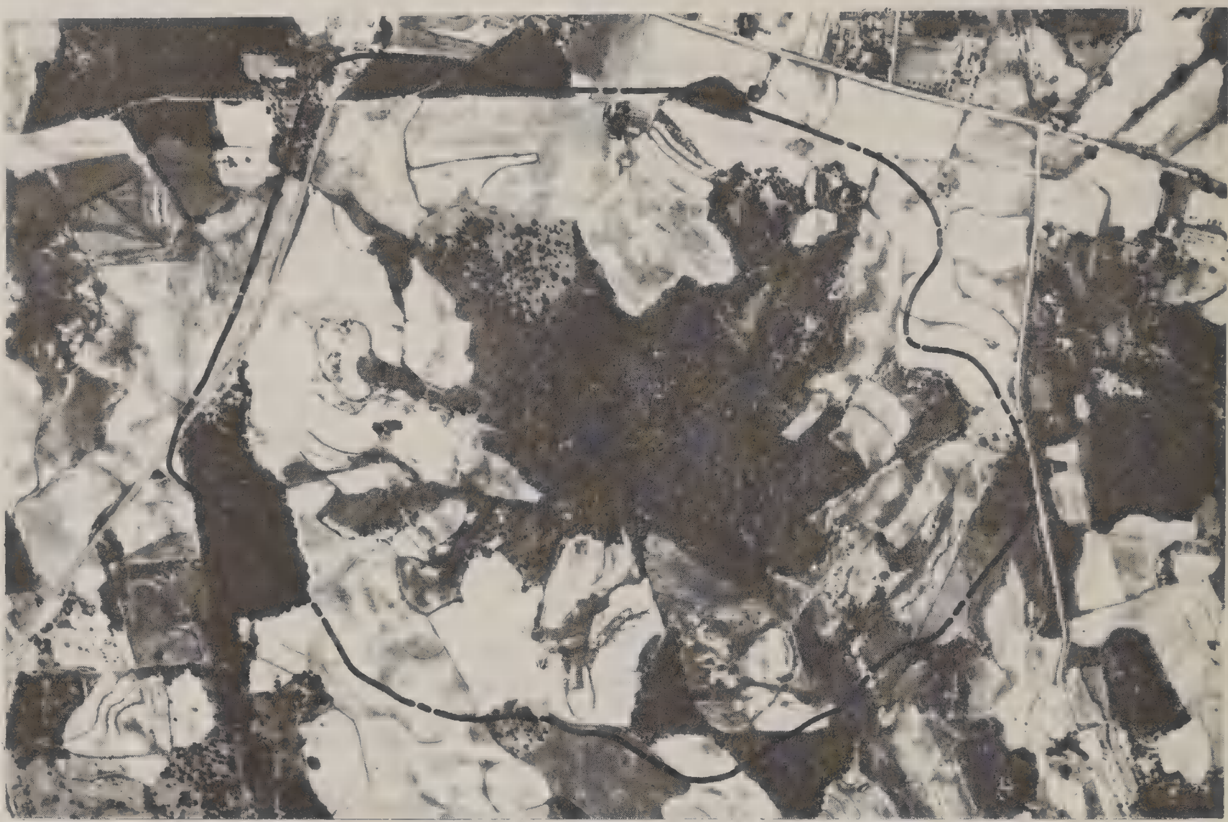

FIGURE I - 1938 airphotograph of Sudbury Watershed, Charlotte, NC

FIGURE II - 1968 airphotograph of Sudbury Watershed, Charlotte, NC

The United States Geological Survey monitored the watershed from 1966 through 1970 (Putnam 1972). Short duration rainstorms of less than 60 minutes produced from 18 to 80% runoff depending upon the antecedent rainfall conditions. Although 27.1% of the watershed is covered by impervious surfaces, only about 18% runoff occurred with dry antecedent conditions. Up to 80% runoff was produced with wet antecedent conditons.

TABLE II
Selected Rainfall Runoff Events[a]
Sudbury Watershed, Charlotte, NC
United States Geological Survey Data

Storm Rainfall cm	One-Day Amt. Rain cm	Peak Runoff cms	Volume Runoff ha-m	Percent Watershed Runoff
4.67	4.85	9.68	5.63	80.4
4.34	6.50	12.76	5.12	78.9
3.51	2.01	6.85	2.15	40.6
3.15	1.04	3.28	1.20	25.4
4.72	0.00	4.08	1.34	18.8
5.00	0.25	3.76	1.39	18.2

[a]All rain events are short duration high intensity storms.

Infiltration tests were conducted across the watershed on various land types (Table III), which were defined by different soil and vegetation conditions. The medium aged pine-mixed hardwood forest conditions had a mean final constant infiltration rate of 31.56 cm/hr. When the forest understory and leaf litter was removed, the resultant residential lawns had a mean infiltration rate of 11.20 cm/hr. Suburban development on old cultivated fields produced a 4.78 cm/hr. mean rate. Four land types of disturbed conditions all had infiltration values less than 2.00 cm/hr. These lower infiltration rates were one to two orders of magnitude less than that for the native forest conditions. Infiltration rates less than 2.00 cm/hr. accounted for about 36% of the watershed. By adding the 27% impervious surfaces, the watershed is essentially 63% "impervious".

The most immediate and economical way to have high infiltration rates after urbanization is to retain as much

undisturbed forest and undisturbed soil areas as possible. This can be done during urbanization through sensitive land planning. The Atlanta Regional Commission is attempting to accomplish this in addition to regulating the amount of impervious surfaces on a large urbanizing watershed in Atlanta.

TABLE III

Infiltration Rates by Land Type for Sudbury Watershed, Charlotte, NC

Land Type	Percent of Watershed	Mean Final Constant Infiltration Rate cm/hr.
Medium aged pine-mixed hardwood forest with leaf litter	2.6	31.56
Slightly disturbed soils with lawns and large trees preserved	23.8	11.20
Slightly disturbed soils, previously cultivated field, lawns and few young trees	9.1	4.78
Slightly disturbed soils, previously cultivated field with plow pan, lawns and few trees	8.7	0.70
Highly disturbed fill soils, lawns and few young trees	7.1	1.25
Highly disturbed cut soils, lawns and few young trees	15.1	0.67
Highly disturbed cut and compacted soils, sparse grass, no trees	4.7	0.45
Wet drainage ways, bottomland hardwoods	1.7	-
Impervious surfaces	27.1	-

The difficult question is how to regain high infiltration rates on those areas inevitably disturbed during development. There are two primary methods to increase infiltration. First is to simply add topsoil. However the addition of topsoil can be extremely expensive. For example, to add an average of 15 cm of topsoil across the soil surfaces on the Sudbury Watershed (see Table IV) it would cost in excess of 2.1 million dollars. The second method recognizes the fact that the critical rainstorm occurs with wet antecedent conditions and that the clayey subsoil porosity controls the soil drainage of the antecedent rainfall. Therefore it is necessary to achieve more rapid downward movement of the antecedent rainfall so that a greater infiltration capacity is developed prior to the critical intense rainstorm. More rapid soil drainage will require deep root development of vegetation, especially trees. Planting of trees species that will root deep into these infertile clayey subsoils would be required.

TABLE IV

Estimated Topsoil, Drainage and/or Rooting Depths Required to Increase Infiltration of Hypothetical 5 cm, 30 Minute Duration Rainstorm with Wet Antecedent Condition, Sudbury Watershed, Charlotte, NC[a]

Increased Infiltration cm	Percent Runoff	Required Topsoil Addition[b] cm	Required Topsoil Addition[b] meters^3 x 10^4	Required 24 hr. Drainage Depth[c] cm	Required Rooting Depth[d] cm
0	80	-	-	-	-
0.5	70	2.5	2.7	10	20
1.0	60	5.0	5.5	20	40
1.5	50	7.5	8.2	30	60
2.0	40	10.0	10.1	40	80
2.5	30	12.5	13.6	50	100
3.0	20	15.0	16.4	60	120

[a]Watershed is 149.9 ha with 109.3 ha of soil surfaces (72.9%).
[b]Topsoil is assumed to have 20% macroporosity.
[c]Required drainage depth assuming subsoil to have 5% macroporosity.
[d]Rooting depth is assumed to be twice the drainage depth.

Most of the common lawn grasses require high levels of fertility to root deeply in these clayey soils. Analysis of soil fertility data on suburban lawns across the watershed indicates extremely infertile conditions. Low levels of P_2O_5 and K_2O and high buffer acidity appears to have severely limited rooting depth. Low phosphorous levels were measured at every sampling location across the watershed and even within 2.5 cm of the soil surface. This rooting depth soil fertility relationship is thought to occur for many of the trees planted across the watershed. This is not to imply that other factors do not control rooting depth, but rather that the soil fertility was so extremely low that it is assumed to be the most limiting factor. Because of the need to deeply incorporate lime and fertilizer, reclamation of these sites would amount to a major and expensive proposition. Merely adding lime and fertilizer to a tree planting hole will not suffice. The best recommendation is the use of native trees and cultivars that are adapted to these relatively infertile soil conditions.

Summary. Sensitive land planning controls and incentives that minimize the destruction of the forests and disturbance of the soils should be considered for inclusion in local urban tree, stormwater management and land planning ordinances. Local recommendations should be developed for the reclamation of disturbed sites. The use of deep rooting trees and grasses that are adapted to the native unamended soils should be recommended.

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ACER to *ZELKOVA*: propagation by cuttings avoids graft incompatibility

by Elwin R. Orton, Jr., Research Professor
Department of Horticulture and Forestry
Rutgers, the State University
New Brunswick, New Jersey 08903

ABSTRACT.--The use of single-node cuttings provides a practical method for the rapid increase of select clones of red maple (*Acer rubrum* L.) and avoids the problem of graft imcompatibility encountered in propagating such plant material by budding. The general technique of propagation by stem cuttings is being extended to the commercial production of many other species of shade and ornamental trees where graft incompatibility has been a problem.

Graft incompatibility constitutes a serious problem in the use of scion cultivars of ~~many different~~ species of shade and ornamental trees. *Acer rubrum* and *Quercus palustris* Muenchh (pin oak) are species in which the graft incompatibility encountered with propagation by budding is of notable economic significance. Graft incompatibility may involve as high as 30 percent of the plants of *A. rubrum* 'October Glory' and other scion cultivars of this species. The incompatibility may be expressed as failure of the scion bud to unite with the seedling *A. rubrum* understock or it may be expressed as delayed incompatibility after one or more years. Fortunately, most of the losses occur in the production nursery before the budded plants attain a height of 8 - 10 feet. However, instances of graft failure occurring after the plants have attained a caliper of 3 - 4 inches are not rare. The economic consequences of graft incompatibility are more severe in cases where the incompatibility is not expressed (or detected) until after the plants are established in a landscape planting. At best, budding is an expensive form of propagation. When the additional cost associated with graft incompatibility is considered, the need for an alternative method of propagation is obvious.

There is a paucity of information relative to the nature of the graft incompatibilities encountered in the important genera and species of shade and ornamental trees. However, that need not preclude a practical solution to the problem(s). Based on the findings of five years of preliminary work, a demonstration study conducted in 1977 (Orton, 1978) proved the efficacy of utilizing single-node stem cuttings as a commercial means of propagating plants of select clones of _A. rubrum_. In addition to requiring less time and being more economical than budding, this method of propagation avoids any problem of graft incompatibility. The work with _A. rubrum_ is reviewed herein.

LARGE CUTTINGS

In preliminary work with _A. rubrum_ 'October Glory', it was found that large three-node cuttings eight to nine inches long and one-third to one-half inch in diameter taken during August and September rooted readily and grew vigorously. However, processing such large cuttings was unwieldly at all stages of the propagation procedure. Also, growth of more than one lateral bud often resulted, and pruning was required to obtain a plant with a single leader. More importantly, commercial production using cuttings of this size would not be feasible, due to the extremely large stock block of parental plant material that would be required. Tip cuttings from lateral shoots also were successfully rooted in preliminary trials, but use of such terminal cuttings also would require a large block of stock plants since each lateral shoot yields only one tip cutting. The use of single-node cuttings is advantageous because many cuttings can be obtained from each stock plant and the space requirements for handling such cuttings are minimal. Also, with the use of single-node cuttings, one can avoid the production of plants with multiple leaders merely by removing the vegetative buds in the axil of one leaf when sticking the cuttings.

SINGLE-NODE CUTTINGS

The principal work reported here was initiated August 7, 1977, for the purpose of demonstrating the efficacy of using single-node stem cuttings to propagate plants of _A. rubrum_. The plant material consisted of 48 lateral branches of current season's growth taken from four-year-old budded plants of 'October Glory' growing at Princeton Nurseries, Princeton, New Jersey.

One tip cutting and an average of 8.6 single-node cuttings were obtained from each lateral branch. Each single-node cutting was cut approximately three-eights inch above and one and one-half inches below the node. A total of 400 single-node cuttings was stuck in a propagation bench

containing four parts sand and one part peat (compressed) by volume. All cuttings were treated with a mixture of Hormodin No. 3 and Benlate (19:1 by volume). Intermittent mist was used. Frequency and duration of misting were six seconds every six minutes from 7 a.m. to 7:30 p.m. the first 11 days, from 8 a.m. to 6 p.m. the following six days and from 10 a.m. to 6 p.m. thereafter. Mist was not used during periods of rain or heavy cloud cover. Night lighting was employed from 10 p.m. to 2 a.m., utilizing 75 watt incandescent bulbs suspended three feet above the bench at a spacing of three and one-half feet. A minimum temperature of 24.5°C (76°F) was maintained in the propagation medium by the use of electric heating cables. Ambient air temperatures in the greenhouse ranged from 21° to 30°C (70° to 86°F) during daylight hours and from 13.3° to 20.6°C (56° to 69°F) at night.

Two levels of two variables (four treatments) were examined in this study: number of axillary buds per cutting (all buds intact vs buds removed from the axil of one leaf) and wounding (no wound vs a heavy wound made by removing a one inch slice from one side of the base of the cutting). A randomized complete block design with four replications of 25 cuttings per treatment was utilized for the 400 single-node cuttings. The cuttings were spaced two and one half inches apart in rows three inches apart. Cuttings in adjoining rows were positioned in an alternate alignment in order to reduce interference of the foliage in sticking the cuttings. The cuttings were inserted in the medium to a depth of approximately one and one-half inches in holes punched with a pointed dibble one-fourth inch in diameter.

The rooted cuttings in replicates 1 and 2 were lifted at 21 days and potted into Zarntainer No.200 containers, utilizing a mixture of two parts peat (compressed), two parts sand and one part soil (by volume). Rooted cuttings in replicates 3 and 4 were harvested at 35 days and potted in one-gallon plastic containers, using medium from the same 2:2:1 mixture. The potted cuttings were examined October 7, 1977 (60 days after sticking the cuttings), to obtain survival data and to record the number of cuttings that exhibited a flush of new growth. Rooting response and plant survival data are presented in Table 1.

Of the 400 single-node cuttings, 392 (98 percent) were rooted heavily at the time of removal from the propagation bench. All four treatments yielded commercially acceptable results regarding both the number of cuttings that rooted and the number of plants surviving on October 7. The numerical differences between treatments shown on Table 1 are not statistically significant. However, the cuttings potted at 21 days subsequently performed better than those potted at 35 days. (Table 2).

Of the 194 cuttings surviving from the 21-day harvest, 139 (72 percent) exhibited new vegetative growth when examined on October 7. Of the cuttings potted after 35 days in the propagation bench, 190 were alive on October 7, but only 63 (33 percent) exhibited new growth on that date. This differential growth response is believed to be a result of the transplant shock received by the cuttings potted at 35 days. The roots of these cuttings were five to eight inches long and were interlocked with the roots of adjacent cuttings such that a stripping action occurred when the cuttings were lifted from the bench. As a result, they came out bareroot and required frequent hand misting for several days following potting. In contrast, the cutting potted at 21 days were removed from the bench with an intact ball of medium adhering to the roots. Cuttings that produce a flush of vegetative growth prior to the winter dormant season constitute stronger plants, which can be overwintered more successfully and will yield more vigorous growth the following year. In preliminary work, plants transplanted to two-gallon containers following overwintering in a plastic greenhouse heated to a minimum temperature of 1°C (34°F) grew as much as six feet the following season when maintained in a greenhouse.

BUD REMOVAL AND WOUNDING

The effects of the different levels of the two variables (number of buds and level of wounding) employed are indicated by the data in Table 3.

Table 1. Effect of number of buds and wounding on rooting and survival of 400 single-node cuttings of A. rubrum 'October Glory'.

Treatment	No. of cutts. rooted in 24 days (Reps. 1 & 2)	No. of cutts. rooted in 35 days (Reps. 3 & 4)	Total Number (and percent) of cuttings rooted 21 and 35 days	No. of Plants Alive 10-7-77
1 Buds intact, no wound	46	48	94	92
2 One bud, no wound	50	50	100	96
3 Buds intact, heavy wound	50	50	100	98
4 One bud, heavy wound	50	48	98	98
Total	196	196	392	384

Table 2. Survival and growth response of rooted cuttings.

Treatment	Number of days in propagation bench	Condition of rooted cuttings on 10-7-77		
		Number alive	New Growth	
			Number	Percent
1 Buds intact, no wound	21	45	32	71
	35	47	18	38
2 One bud, no wound	21	49	33	67
	35	47	10	21
3 Buds intact, heavy wound	21	50	41	82
	35	48	15	31
4 One bud, heavy wound	21	50	33	66
	35	48	20	42
Total	21	194	139	72
	35	190	63	33

Table 3. Effect of number of buds and wounding on rooting and on growth response of the rooted cuttings.

Experimental variable	Average of treatments	Number of cuttings rooted	Condition of rooted cuttings on 10-7-77		
			Number alive	New Growth Number	New Growth Percent
Buds intact	1 & 3	194	190	106	56
One bud	2 & 4	198	194	96	49
No wound	1 & 2	194	188	93	49
Heavy wound	3 & 4	198	196	109	56

Neither removal of buds in the axil of one leaf at the time the cuttings were stuck nor heavy wounding of the cuttings had a demonstrable effect on rooting and survival of the plant material or on the early growth response of the rooted cuttings. Thus, it would appear that removal of buds at the time unrooted cuttings of *A. rubrum* are processed can be substituted for later pruning to achieve plants with a single leader.

Wounding the cuttings might have been expected to result in increased absorption of the synthetic root-promoting growth regulator (IBA) utilized, but no inhibitory effect on budbreak was evident. Fifty-six percent of the wounded cuttings exhibited a new flush of vegetative growth at 60 days, compared with 49 percent for the unwounded cuttings. However, wounding did influence the position on the cutting at which roots formed. Root initiation occurred at the basal portion of unwounded cuttings, whereas, on wounded cuttings, roots emerged directly above the wound as well as at the base of the cuttings.

Stimulation of rooting above the wound could prove to be beneficial in commercial production of such plant material in the event of a temporary period of overwatering. It was observed in preliminary work with cuttings of *A. rubrum* that newly formed roots die and turn black quickly when overwatered either while in the propagation bench or immediately following potting. However, root regeneration was rapid once the medium became drier. Thus roots formed high on the cuttings (above the wound) might be less subject to dieback in the event of a short period during the propagation process when excess water is present in either the propagating or the growing medium.

TIP CUTTINGS

The 48 bud sticks utilized as a source of the 400 single-node cuttings discussed above provided 48 tip cuttings. These cuttings possessed three to five nodes each, were five to seven inches long and were handled under the same conditions as the single-node cuttings, except that the more succulent nature of the plant material necessitated more frequent misting.

Of the 48 tip cuttings, 46 (96 percent) were heavily rooted and possessed roots five to eight inches long when potted (53 days). The shearing effect of the interlocked roots bare-rooted the cuttings at lifting and caused considerable transplant shock. Thus, it was nec-

essary to provide shade and frequent misting in order to establish the plants following potting. Undoubtedly, the need for this special treatment would have been avoided had the cuttings been lifted from the propagation bench at 35 days.

MATURE CUTTINGS

In addition to the main study discussed above, which involved cuttings from juvenile plants, cuttings from a mature specimen of 'October Glory' were utilized in an attempt to demonstrate further the relative ease with which plants of A. rubrum 'October Glory' can be propagated from stem cuttings.

July 20, 1977, 60 single-node cuttings and 33 tip cuttings were taken from lateral shoots of a mature specimen (22 years from budding) growing at the Rutgers University research and display garden, New Brunswick, N. J. The tree was growing under drought conditions such that none of the lateral shoots provided more than two single-node cuttings plus a three to four-inch terminal cutting. Handled in the same manner as the single-node and tip cuttings, respectively, of the main study, 53 (88 percent) of the 60 single-node cuttings and five (33 percent) of the terminal cuttings were heavily rooted at the time of potting (10 weeks). A few of these cuttings produced new growth and flowered during this period.

A small number of cuttings of A. rubrum 'Red Sunset' was stuck August 8, 1977, in an attempt to demonstrate that the ease with which stem cuttings of this species can be rooted is not limited to cuttings of the cultivar 'October Glory'. Thirteen cuttings from one bud stick of 'Red Sunset' were stuck in the same propagation bench as the single-node cuttings of 'October Glory'. All 13 cuttings were rooted when lifted from the bench 16 days later.

In addition, 40 cuttings (including wounded and non-wounded single-node and two-node cuttings) were obtained from five lateral shoots of four-year-old budded plants of 'Red Sunset'. These cuttings were stuck in a medium of two parts peat (compressed), seven parts sand and one part soil (by volume) in Jiffy pots No. 335 ($3\frac{1}{2}$ inch). The pots were placed in two wooden flats, which were set on top of the medium in the propagation bench. After 14 days, the flats were removed from the mist bench and placed on a standard greenhouse bench under lights (10 p.m. to 2 a.m.) as used over the propagation bench. At 28 days after sticking the cuttings, many roots had penetrated the peat pots. In each flat, 19 of the 20 cuttings rooted.

Handling the cuttings in individual pots eliminated the transplanting operation; furthermore, in commercial practice, a flat containing 20 plants would constitute an economical unit to transport to the field.

These studies with 'October Glory' and 'Red Sunset' showed that the use of single-node stem cuttings is a simple method for the rapid increase of plants of select clones of _A. rubrum_. This work was conducted in cooperation with Princeton Nurseries, and, as preliminary results were obtained, the information was shared with personnel at Moller's Nursery, a major producer of ornamental and shade trees in Oregon. As reported by Schwab (1979), Moller's nursery has now extended the list of trees propagated by cuttings to include plants of flowering crab apples (_Malus_), flowering plums (_Prunus_),flowering cherries (_Prunus_), _Amelanchier canadensis_, Katsuratree (_Cercidiphyllum_), cultivars of silver maple (_Acer saccharinum_ and the Lindens (_Tilia_).

At present, graft incompatibility remains a major problem in the production of the 'Sovereign' pin oak and select clones of other members of the black oak group. However, preliminary attempts at Rutgers University to propagate plants of the black oak group by means of stem cuttings have yielded encouraging results. Thus, the addition of these plant materials to the list of plants propagated by stem cuttings may not be far in the future. Once the demand for specific cultivars of these species provides the economic incentive, commercially acceptable techniques for propagating such plant materials from stem cuttings most likely will be achieved rather quickly.

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ELECTION OF OFFICERS

The Nominating Committee, chaired by William Collins, in accordance with the Constitution, presented a slate of candidates for consideration by the membership. The following are the METRIA officers.

Executive Director

Ralph Veverka
4804 West 58th Street
Cleveland, OH 44101

Assistant Director

David F. Karnosky
Cary Arboretum
Millbrook, NY 12545

Secretary-Treasurer

Kim C. Steiner
313 Forest Resources Lab
University Park, PA 16802

Executive Council

Continuing:

F. Raymond Brush
American Association of Nurserymen
Southern Building
Washington, D.C. 20005

New:

Richard Abbott
Davey Tree Expert Company
Kent, OH 44240

Robert Cool
1608 Kingswood Drive
Lansing, MI 48924

Larry Kuhns
103 Tyson Building
University Park, PA 16802

William Wandel
Wandel's Nursery, Inc.
RR 3, Myra Station Road
Urbana, IL 61801

George Ware
The Morton Arboretum
Lisle, IL 60532

Brennan, Eileen - Department of Plant Biology, Cook College, Box 231, New Brunswick, NJ 08901

Craul, Phillip J. - SUNY, College of Environmental Science and Forestry, Syracuse, NY 13210

Collins, William - Amer Garden Cole, 30627 Orr Road, Circleville, OH 43113

Davis, Spencer H., Jr. - Department of Plant Pathology, Rutgers University, Box 231, New Brunswick, NJ 08903

Douglas, Robert W. - 1057 Papan Road, Bridgewater, NJ 08807

Flemer, William - Princeton Nursery, Princeton, NJ 08540

Funk, David T. - USDA Forest Service, Box 640, Durham, NH 03824

Gerhold, Henry D. - Forest Resources Lab., University Park, PA 16802

Guerra, Marilyn - 8400 D'Arcy Road, Forestville, MD 20028

Hamilton, Bruce - Department of Horticulture, Cook College, Box 231, New Brunswick, NJ 08903

Kays, Barrett L. - 411 N. Boylan Avenue, Raleigh, NC 27603

Karnosky, David F. - Cary Arboretum, Millbrook, NY 12545

Kuhns, Larry J. - 103 Tyson Building, University Park, PA 16802

Kulik, Michael - 35 Hillcrest Drive, Wayne, NJ 07470

Leone, Ida - Department of Plant Biology, Cook College, Box 231, New Brunswick, NJ 08901

McCormick, Larry - 204 B Ferguson Building, University Park, PA 16802

Orton, Elwin - Box 231, Cook College, New Brunswick, NJ 08903

Patterson, James C. - 2821 Baker Drive, Silver Springs, MD 20904

Perry, Thomas O. - Box 5488, NC State University, Raleigh, NC 27606

Rau, Doug - 1355 McAfee Street, St. Paul, MN 55106

Rhoads, Ann F. - 9412 Meadowbrook Avenue, Philadelphia, PA 19118

Sacksteder, C.J. - 301 Forest Resources Lab., University Park, PA 16802

Sandorf, Steve - 950 Eden Park Drive, Cincinnati, OH 45202

Santamour, Frank S., Jr. - US National Arboretum, Washington, DC 20002

Schutzki, Robert - Hunterdown County Extension Service, Route 31, RD 6, Box 48, Flemington, NJ 08822

Simmons, Michael L. - RD 1, Box 409, Jersey Shore, PA 17740

Sperapani, Clare - County Administration Building, Somerville, NJ 08876

Steiner, Kim C. - 313 Forest Resources Lab., University Park, PA 16802

Sydnor, T. Davis - 6800 Harriott Road, Powell, OH 43065

Tate, Robert - Box 231, Cook College, New Brunswick, NJ 08901

Taylor, Tom - 212A Eaton Drive, Eatontown, NJ 07724

Townsend, Alden M. - USDA-SEA Nursery Crops Lab., Delaware, OH 43015

Valentine, Frederick A. - 6835 Woodchuck Hill Road, Fayetteville, NY 13066

Vergara, Scott G. - Box 3095, New Brunswick, NJ 08902

Ververka, Ralph M. - 4804 W. 58th Street, Cleveland, OH 44144

Wandell, Willet N. - RR 3, Myra Station, Urbana, IL 61801

Ware, George - Morton Arboretum, Lisle, IL 60532

Watt, Richard F. - Northeast Area-S&PF, 380 Reed Road, Broomwell, PA 19008

Wurdeman, Mark A. - 2300 Silvercreek Road, NE, Rochester, MN 55901

Zafonte, Charles - County Administration Building, 317 Pennsylvania Avenue, Paterson, NJ 07503

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